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[illegible] Translation [illegible] M.A., F.R.S. [illegible] Trees of the [illegible] and Animals. 2 vols. [illegible]

[illegible] Translated by [illegible]

[illegible] AND TEACHING. [illegible]

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THE

OLUTION OF MAN:

OPULAR EXPOSITION OF THE PRINCIPAL S OF HUMAN ONTOGENY AND PHYLOGENY.

FROM THE GERMAN OF

ERNST HAECKEL,

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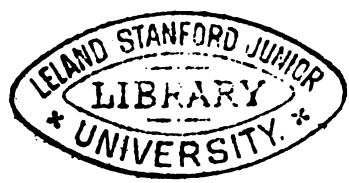

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THE EVOLUTION OF MAN.

CHAPTER XV.

THE DURATION OF HUMAN TRIBAL HISTORY.

Comparison of Ontogenetic and Phylogenetic Periods of Time.—Duration of Germ-history in Man and in Different Animals.—Extreme Brevity of the Latter in Comparison with the Immeasurable Long Periods of Tribal History.—Relation of this Rapid Ontogenetic Modification to the Slow Phylogenetic Metamorphosis.—Estimate of the Past Duration of the Organic World, founded on the Relative Thickness of Sedimentary Rock-strata, or Neptunian Formations.—The Five Main Divisions in the Latter: I. Primordial, or Archilithic Epoch. II. Primary, or Palæolithic Epoch. III. Secondary, or Mesolithic Epoch. IV. Tertiary, or Cænolithic Epoch. V. Quaternary, or Anthropolithic Epoch.—The Relative Duration of the Five Epochs.—The Results of Comparative Philology as Explaining the Phylogeny of Species.—The Inter-relations of the Main Stems and Branches of the Indo-Germanic Languages are Analogous to the Inter-relations of the Main Stems and Branches of the Vertebrate Tribe.—The Parent Forms in both Cases are Extinct.—The Most Important Stages among the Human Ancestral Forms.—Monera originated by Spontaneous Generation.—Necessity of Spontaneous Generation.

"In vain as yet has it been attempted to draw an exact line of demarcation between historic and prehistoric times; the origin of man and the period of his first appearance pass back into indefinable time; the so-called archaic age cannot be sharply distinguished from the present age. This is the fate of all geological, as of all historical periods. The periods which we distinguish are, therefore, more or less arbitrarily defined, and, like the divisions

in systematic natural history, can only serve to bring the subject of our study better before us and to render it more manageable; but not to make real distinctions between different things."—BERNHARD COTTA (1866).

OUR comparative study of the Anatomy and Ontogeny of the Amphioxus and the Ascidian has afforded us aid, the value of which can hardly be over-estimated, toward acquiring a knowledge of human Ontogeny. For in the first place we have in this way filled up, as regards Anatomy, the wide chasm which in all previous systems of the animal kingdom existed between Vertebrates and Invertebrates; and in the second place, in the germ-history of the Amphioxus we have recognized primordial phases of development, which have long disappeared from the Ontogeny of Man, and which have been lost in accordance with the law of abridged heredity. Of special importance among these phases of development is the Archigastrula, the original, genuine Gastrula-form which the Amphioxus has retained up to the present time, and which re-appears in the same form in low invertebrate animals of the most diverse classes.

The germ-history of the Amphioxus and the Ascidian has, therefore, so far perfected our direct knowledge of human genealogy, that, notwithstanding the incompleteness of our empiric knowledge, there is no essential gap of any great moment in the pedigree. We may, therefore, at once proceed to our task, and, aided by the ontogenetic and comparative-anatomical materials at our command, may reconstruct the main outlines of human Phylogeny. The immense importance of the direct application of the fundamental biogenetic law of the causal connection between Ontogeny and Phylogeny now becomes evident. But, before

beginning this task, it will be well to note a few other general facts which may enable us better to understand the phenomena we are about to study.

Firstly, it may not be out of place to insert a few remarks as to the duration of time during which Man was developing from the animal kingdom. The first thought that occurs to the mind when we consider the facts in question, is of the immense difference between the duration of the germ-history of Man on the one hand, and of his tribal history on the other. The brief period in which the Ontogeny of the human individual takes place, bears no proportion to the infinitely long period required for the Phylogeny of the human tribe. The human individual requires nine months for its perfect development from the fertilized egg-cell to the moment at which it is born and quits the mother's body. The human embryo, therefore, passes through the whole course of its development in the brief space of 40 weeks (usually in exactly 280 days). Each man is really older by this period than is usually assumed. When, for example, a child is said to be 9¼ years old, he is in reality 10 years old. For individual existence does not begin at the moment of birth, but at the moment of fertilization. In many other Mammals the duration of the embryonic development is the same as in Man, *e.g.*, the Ox. In the Horse and the Ass it is somewhat longer, viz., from 43 to 45 weeks; in the Camel it is 13 months. In the largest Mammals the embryo requires a much longer time for its complete formation within the maternal body; in the Rhinoceros, for instance, 1½ year, in the Elephant 90 weeks. In the latter case, therefore, gestation lasts more than twice as long as in Man—for

nearly a year and three quarters. In the smaller M the duration of embryonic development is, on the c much shorter. The smallest Mammals, the Harve develop fully in 3 weeks; Rabbits and Hares in 4 Rats and Marmots in 5 weeks; the Dog in 9, the P the Sheep in 21, and the Stag in 36 weeks. Develo yet more rapid in Birds. The Chick, under nor ditions of incubation, requires only 3 weeks, or just for its full development. The Duck, on the othe takes 25, the Turkey 27, the Peacock 31, the Swan the New Holland Cassowary 65 days. The smalle Birds, the Humming-bird, quits the egg after the twe It is, therefore, evident that in Mammals and in B duration of development within the egg-membrane in a definite relation to the size of body attained vertebrate species. But the latter is not the sole d ing cause of the former. There are many other stances which influence the duration of individual ment within the membranes of the egg.[126]

In all cases, however, the duration of the O appears infinitely brief when compared with the er the infinitely long period during which the Phylo gradual development of the ancestral series, too This period is not to be measured by years and c but by thousands and millions of years. Many mi years must indeed have elapsed while the most vertebrate organism, Man, gradually developed fi primæval one-celled ancestral organism. The oppo the development theory, who regard this gradual ment of Man from lower animal forms, and his descent from a one-celled primitive animal as in

o not reflect that the very same marvel actually recurs efore our eyes in the short space of nine months during he embryonic development of each human individual. The same series of multifariously diverse forms, through which our brute ancestors passed in the course of many nillions of years, has been traversed by every Man during he first 40 weeks of his individual existence within the naternal body.

All changes in organic forms, all metamorphoses of nimal and plant forms, appear to us all the more remark-ble and all the more wonderful in proportion as they occur nore rapidly. When, therefore, our opponents pronounce that he past development of the human race from lower animal forms is incredible, they must regard the embryonic develop-ment of the human individual from the simple egg-cell as far more wonderful in comparison. This latter process—the ontogenetic modification—which takes place before our eyes, must appear more wonderful than the phylogenetic modifi-cation, in proportion as the duration of the tribal history exceeds that of the germ-history. For the human embryo must pass through the whole process of individual develop-ment, from the simple cell up to the many-celled perfect Man, with all his organs, in the brief space of 40 weeks. On the other hand, we may assign many millions of years for the accomplishment of the analogous process of phyloge-netic development—the development of Man's ancestors from the simplest one-celled form.

As regards these phylogenetic periods, it is impossible to fix approximately their length in hundreds or in thousands of years, or to establish any absolute measure of their duration. But the researches of geologists have long since

enabled us to estimate and compare the relative durations of the various periods of the earth's organic history. The most direct standard for determining the relative duration of geological periods is afforded by the thickness of the so-called Neptunian strata or sedimentary rock, *i.e.*, all those strata which have been deposited, as mud, at the bottom of the ocean, or under fresh water. These stratified sedimentary rocks—limestone, clay, marl, sandstone, slate, etc.—which constitute the great mass of mountain-chains, and which are often several thousand feet in thickness, afford us data for estimating the relative lengths of the various periods of the earth's history.

For the sake of completeness, I must say a few words as to the development of the earth as a whole, briefly indicating a few of the more prominent facts relating to this matter. At the very outset we are confronted with the weighty fact, that life originated on our planet at a certain definite period. This is a proposition that is no longer gainsaid by any competent geologist. We now know for certain that organic life upon our planet actually began at a certain time, and that it did not exist there from eternity, as some have supposed. The indisputable proofs of this are furnished, on the one hand, by physico-astronomical cosmogeny; on the other, by the Ontogeny of organisms. Species and tribes, like individuals, do not enjoy a perpetual life.[127] They also had a beginning. The time which has elapsed since the origin of life upon the earth up to the present time (and with this period of time alone we are here concerned) we call the "history of the organic earth," as distinguished from the "history of the inorganic earth" which embraces the period before the origin of organic life.

regard to the latter, we first obtained clear ideas from natural philosophical researches and computations of great critical philosopher, Immanuel Kant, and on this I must refer the reader to Kant's "Allgemeine Naturichte und Theorie des Himmels" and to the numerous logenies which treat the subject in a popular style. annot here dwell upon questions of this kind.

he organic history of the earth could begin only when r in fluid drops existed upon its surface. For the very ence of all organisms, without any exception, depends ater in the fluid state, their bodies containing a conable amount of the same. Our own body, in its fully oped state, contains in its tissues 70 per cent. of water nly 30 per cent. of solid matter. The amount of water ll greater in the body of the child, and is greatest of all e embryo. In early stages of development the human yo contains more than 90 per cent. of water, and not er cent. of solid matter. In low marine animals, ially in the Medusæ, the body contains even more than er cent. of water, and not even one per cent. of solid ar. No organism can exist and perform its vital ions without water. Without water there is no life.

Vater in the fluid state, which is, therefore, insable for the existence of life, could not, however, ar upon the earth until after the temperature of the ce of the fiery globe had sunk to a certain point. e this it existed only in the form of steam. As however, as the first drop of water in a fluid state was pitated by cooling from the envelope of steam, it began eological action, and from that time to this it has ed continual changes in the modification of the hard

crust of the earth. The result of this unceasing work of the water, which in the form of rain and hail, of snow and ice, of rushing torrent and surging wave crumbles and dissolves the rocks, is the formation of ooze. As Huxley says, in his excellent "Lectures on the Causes of the Phenomena of Organic Nature," the most important fact in the past history of our earth is ooze, and the question as to the history of the past ages of the world resolves itself into a question as to the formation of ooze. All the stratified rocks of our mountainous formations were originally deposited as ooze at the bottom of the waters, and only afterwards hardened into solid stone.

As has already been said, it is possible, by bringing together and comparing the various rock-strata from many places on the surface of the earth, to obtain an approximate conception of the relative ages of these various strata. Geologists have long agreed that there is an entirely definite historical sequence of the various formations. The various groups of strata which lie one over another correspond to successive periods in the earth's organic history, during which they were deposited in the shape of mud at the bottom of the sea. Gradually this mud was hardened into solid rock. The latter, by alternate upheaval and depression of the surface of the earth, was lifted above the water, and assumed the form of mountains. Four or five main periods in the earth's organic history, answering to the larger and smaller groups of these sedimentary rock-strata, are usually distinguished. These main periods are subdivided into numerous subordinate or lesser periods. From twelve to fifteen of the latter are usually assumed. (Cf. Tables XII. and XIII., pp. 11, 12.) The relative thick-

of the various groups of strata affords the means of oximately estimating the relative length of these various ions of time. Of course we cannot say, "In a hun- years on the average a stratum of a certain thick- (say two inches) is deposited, and therefore a rock- um of a thousand feet in thickness is 600,000 s old." For different rock-formations of equal thick- may have occupied periods of very various length eir deposition and consolidation. From the thickness e formation we may, however, approximately judge of *relative* length of the period during which it was ed.

)f the four or five main periods of the earth's organic ry, our acquaintance with which is indispensable for Phylogeny of the human race, the first and oldest is vn as the Primordial, Archizoic, or Archilithic Epoch. e estimate the total thickness of all the sedimentary a as averaging about 130,000 feet, then 70,000 feet belong is first epoch—more than one half. From this and other mstances we may conclude that the corresponding ordial or Archilithic Epoch must alone have been con- ably longer than the whole long period between the of the Archilithic and the present time. Probably the ordial Epoch was much longer than might appear from atio of 7 : 6, which we have given. This Epoch is divided three sub-periods, known as the Laurentian, Cambrian, Silurian, corresponding to the three principal groups of nentary rock-strata which constitute the Archilithic a. The enormous length of time required for the forma- at the bottom of the primordial sea of these gigantic a, of over 70,000 feet in thickness, must, at all events,

have been many millions of years. During that time there came into existence by spontaneous generation the oldest and simplest organisms—those in which life began upon our planet—viz., the Monera. From these, one-celled plants and animals first developed—the Amœbæ and many kinds of Protista. During this same Archilithic Epoch, also, all the invertebrate ancestors of the human race developed from these one-celled organisms. We draw this conclusion from the fact that towards the close of the Silurian period a few remains of fossil Fishes are already to be found, viz., Selachians and Ganoids. These are, however, much more highly organized and of later origin than the lowest Vertebrates (the Amphioxus), or than the various skull-less Vertebrates allied to Amphioxus, which must have lived during this time. The latter must necessarily have been preceded by all the invertebrate ancestors of man. Hence we may characterize this entire epoch as the "age of man's invertebrate ancestors;" or, with special reference to the oldest representatives of the Vertebrate tribe, as the "age of Skull-less Animals." During the whole Archilithic Epoch the inhabitants of our planet consisted exclusively of aquatic forms; at least, no remains of terrestrial animals or plants dating from this period have as yet been found. A few remains of land-dwelling organisms which are sometimes referred to the Silurian Period, are Devonian.

The Primordial Epoch was followed by the Palæolithic, Palæozoic, or Primary Epoch, which is also separable into three sub-periods: the Devonian, the Carboniferous, and the Permian. During the Devonian Period the Old Red Sandstone, or Devonian system was formed; during the Carboniferous, those great beds of coal were deposited which

TABLE XII.

atic Survey of the Palæontological Periods, or the Greater Divisions in the History of the Organic Earth.

I. *First Epoch:* **The Archilithic,** *or Primordial Epoch.*
(Age of Skull-less Animals and Seaweed Forests.)

e Older Archilithic Epoch	or	Laurentian Period.
e Middle Archilithic Epoch	„	Cambrian Period.
e Later Archilithic Epoch	„	Silurian Period.

II. *Second Epoch:* **The Palæolithic,** *or Primary Epoch.*
(Age of Fishes and Fern Forests.)

e Older Palæolithic Epoch	or	Devonian Period.
e Middle Palæolithic Epoch	„	Coal Period.
e Later Palæolithic Epoch	„	Permian Period.

III. *Third Epoch:* **The Mesolithic,** *or Secondary Epoch.*
(Age of Reptiles and Pine Forests, *Coniferæ.*)

e Older Mesolithic Epoch	or	Triassic Period.
e Middle Mesolithic Epoch	„	Jurassic Period.
e Later Mesolithic Epoch	„	Chalk Period.

IV. *Fourth Epoch:* **The Cænolithic,** *or Tertiary Epoch.*
(Age of Mammals and Leaf Forests.)

e Older Cænolithic Epoch	or	Eocene Period.
e Middle Cænolithic Epoch	„	Miocene Period.
e Later Cænolithic Epoch	„	Pliocene Period.

V. *Fifth Epoch:* **The Anthropolithic,** *or Quaternary Epoch.*
(Age of Man and Cultivated Forests.)

e Older Anthropolithic Epoch	or	Ice Age, Glacial Period.
e Middle Anthropolithic Epoch	„	Post Glacial Period.
e Later Anthropolithic Epoch	„	Period of Culture.

e Period of Culture is the Historic Period, or Period of Tradition.)

TABLE XIII.

Systematic Survey of the Palæontological Formations, or the Fossiliferou Strata of the Earth's Crust.

Rock-Groups.	*Systems.*	*Formations.*	*Synonyms of Formations.*
V. *Quaternary Group,* or Anthropolithic (Anthropozoic) groups of strata	XIV. Recent (Alluvium)	36. **Present**	Upper alluvial
		35. **Recent**	Lower alluvial
	XIII. Pleistocene (Diluvium)	34. **Post glacial**	Upper diluvial
		33. **Glacial**	Lower diluvial
IV. *Tertiary Group,* or Cænolithic (Cænozoic) groups of strata	XII. Pliocene (New tertiary)	32. **Arvernian**	Upper pliocene
		31. **Sub-Appenine**	Lower pliocene
	XI. Miocene (Middle tertiary)	30. **Falunian**	Upper miocene
		29. **Limburgian**	Lower miocene
	X. Eocene (Old tertiary)	28. **Gypsum**	Upper eocene
		27. **Nummulitic**	Middle eocene
		26. **London clay**	Lower eocene
III. *Secondary Group,* or Mesolithic (Mesozoic) groups of strata	IX. Cretaceous.	25. **White chalk**	Upper cretaceous
		24. **Green sand**	Middle cretaceous
		23. **Neocomian**	Lower cretaceous
		22. **Wealden**	The Kentish Weal
	VIII. Jura	21. **Portlandian**	Upper oolite
		20. **Oxfordian**	Middle oolite
		19. **Bath**	Lower oolite
		18. **Lias**	Lias formation
	VII. Trias	17. **Keuper**	Upper trias
		16. **Muschelkalk**	Middle trias
		15. **Bunter sand**	Lower trias
II. *Primary Group,* or Palæolithic ("alæozoic) groups of strata	VI. Permian (New red sandstone)	14. **Mountain limestone** (*Zechstein*)	Upper Permian
		13. **Red sandstone**	Lower Permian
	V. Carboniferous (Coal)	12. **Carboniferous sandstone**	Upper carbonifer ous
		11. **Carboniferous limestone**	Lower carbonifer ous
	IV. Devonian (Old red sandstone)	10. **Pilton**	Upper Devonian
		9. **Ilfracombe**	Middle Devonian
		8. **Linton**	Lower Devonian
I. *Primordial Group,* or Archilithic (Archizoic) groups of strata	III. Silurian	7. **Ludlow**	Upper Silurian
		6. **Wenlock**	Middle Silurian
		5. **Llandeilo**	Lower Silurian
	II. Cambrian	4. **Potsdam**	Upper Cambrian
		3. **Longmynd**	Lower Cambrian
	I. Laurentian	2. **Labrador**	Upper Laurentia
		1. **Ottawa**	Lower Laurenti

pply us with our principal fuel; in the Permian, the ew Red Sandstone, the Magnesian Limestone (Zechstein), d the Cupriferous Slate were formed. The approxi-ate thickness of this entire group of strata is esti-ated at 42,000 feet at most; some geologists make it mewhat more, others considerably less. In any case, is Palæolithic Epoch, taken as a whole, is consider-ly shorter than the Archilithic, but yet is considerably ger than all the following Epochs taken together. The ata deposited during this Primary Epoch supply fossil imal remains in great abundance; besides numerous ecies of Invertebrates we find also very many Verte-ates—Fishes preponderating. As early as the Devonian, d even during the Carboniferous and the Permian riods, there existed so great a number of Fishes, espe-lly Primitive Fishes (Sharks) and Ganoids, that we may signate the entire Palæolithic Period as the *Age of Fishes.* e Palæozoic Ganoids especially are represented by a ge number of forms.

But even during this period some Fishes began to custom themselves to living upon the land, and thus gave e to the Amphibian class. Even in the carboniferous stem we find fossil remains of Amphibia—the earliest restrial and air-breathing animals. In the Permian riod the variety of these Amphibia becomes greater. To-rds its close the first Amnion-animals, the tribal ancestors the true higher Vertebrate classes, seem first to appear. ese are a few lizard-like animals, of which the Protero-urus from the Cupriferous Slate at Eisenach is the best own. The appearance of the most ancient Amnion imals (*Amniota*), to which the common parent-form of

Reptiles, Birds, and Mammals must have belonged, see in fact to be referred by these oldest reptilian remains ba to the close of the Palæolithic Epoch. During this Epo the ancestors of the human race must accordingly ha been represented, first by true Fishes, then by Mud-Fis (*Dipneusta*) and Amphibia, and finally by the old Amnion Animals, the Protamnia.

After the Palæolithic Epoch comes a third main divi of the earth's organic history, known as the Mesolithi Secondary Epoch. This is again distinguished into t subdivisions—the Triassic, the Jurassic, and the Cretac Periods. The approximate thickness of the strata-gro formed during these three Periods from the beginnin the Triassic down to the end of the Cretaceous Pe amounts in all to about 15,000 feet, not one half the th ness of the Palæolithic deposits. During this Epoch a great and varied development took place in all division the animal kingdom. In the vertebrate tribe especial number of new and interesting forms developed. An Fishes the Osseous Fishes (*Teleostei*) now first appear. the Reptiles surpass all others both in numbers an diversity of species—the most remarkable and the r familiar forms being the gigantic extinct Dragons (D saurians), the Sea-Dragons (Halisaurians), and the Fl Lizards (Pterosaurians). In reference to this predominan the reptilian class this time is known as the *age of rept* But the class of Birds also developed during this pe undoubtedly originated from a branch of the lizard- Reptiles. This is shown by the similar embryology of B and of Reptiles, by their Comparative Anatomy, and als the fact that we know of fossil birds with toothed j

d with lizard's tail, belonging to this period (*Odon-*
mis Archæopteryx). Finally, it was during this period
t there appeared upon the scene that most perfect and,
us, most important vertebrate class, the mammalian
a. The oldest fossil remains of these have been found
the most recent Triassic strata, viz., molar teeth of
all insectivorous Pouched Animal (Marsupial). Numer-
remains occur somewhat later in the Jura system, and
w in the chalk. All the remains of Mammals from this
olithic Epoch with which we are acquainted belong to
low Pouched Animal division; and among these were
ubtedly the ancestors of Man. On the other hand,
a single undisputed relic has yet been discovered
ughout all this period of one of the higher Mammals
centalia). This last division, of which Man is a member,
not develop till later, in the immediately subsequent
iary Epoch.

The fourth main division of the history of the organic
, the Tertiary, Cænozoic, or Cænolithic Epoch, was of
h shorter duration than the preceding. For the strata
sited during this period are in all only about 3000 feet
ickness. This Epoch, also, is divided into three sub-
ions, known as the Eocene, Miocene, and Pliocene
ds. During these periods the most diverse develop-
t of the higher classes of plants and animals took place
the fauna and flora of our globe now approached
er and nearer to their present character. The most
ly developed class of animals, that of Mammals, now
ned pre-eminence. This Tertiary Epoch may, therefore,
alled the *age of Mammals*. The most perfect section
his class, the Placental Animals, among which is Man,

now first appeared. The first appearance of Man-
speak more correctly—the development of man fr
most nearly allied ape-form, dates probably either fr
Miocene or the Pliocene Period,—from the middle
latest section of the Tertiary Epoch. Perhaps, as is a
by others, Man strictly so-called, *i.e.*, Man gifted
language, first developed from the speechless man-lik
in the subsequent Anthropolithic Age.

At all events, the perfect development and distri
of the various races of Man dates from the fifth a
main division of the organic history of the earth, and
this Epoch has been called the Anthropolithic, or A
pozoic, and also the Quaternary Epoch. It is true t
the present imperfect state of our palæontologic
prehistoric knowledge, we cannot solve the problem
whether the development of Man from the nearest
Ape-forms took place in the beginning of this Anthro
Epoch, or as early as the middle or towards the close
preceding Tertiary Epoch. This much, however, is c
that the true development of human culture date
from the Anthropolithic Epoch, and that this latte
stitutes only an insignificantly small section of the
enormous period of time occupied in the developm
the organic earth. When we reflect upon this, it a
absurd to speak of the brief span of man's period
ture as "the world's history." This so-called Hist
the World does not amount approximately to eve
half per cent. of the length of those enormous
which have passed away from the beginning of the
organic history down to the present time. For this V

istory, or more correctly, History of People, is itself nly the latter half of the Anthropolithic Epoch, while ven the first half of this Epoch must be reckoned as a rehistoric period. Hence this last main period, reaching om the close of the Cænolithic Epoch to the present time, an only be called the "age of man," inasmuch as the iffusion and differentiation of the different species and ces of man, which have so powerfully influenced all the st of the organic population of the globe, took place uring its course.

Since the awakening of the human consciousness, uman vanity and human arrogance have delighted in garding Man as the real main-purpose and end of all rthly life, and as the centre of terrestrial Nature, for whose e and service all the activities of the rest of creation were om the first defined or predestined by a "wise providence." ow utterly baseless these presumptuous anthropocentric nceptions are, nothing could evince more strikingly than comparison of the duration of the Anthropozoic or Quaterry Epoch with that of the preceding Epochs. For even ough the Anthropolithic Epoch may embrace several hunds of thousands of years, how small is this time when mpared with the millions of years that have elapsed since e beginning of the world's organic history down to the st appearance of the human race!

If the entire duration of the organic history of the earth, m the generation of the first Monera down to the present y, is divided into a hundred equal parts, and if then, responding with the relative average thickness of the ervening strata-systems, the respective percentages are

assigned to the relative durations of the five main division or Epochs, the latter will be found to be about as follows:—

I.	Archilithic, or archizoic (primordial) Epoch . .	53.6
II.	Palæolithic, or palæozoic (primary) Epoch . .	32.1
III.	Mesolithic, or mesozoic (secondary) Epoch . .	11.5
IV.	Cænolithic, or cenozoic (tertiary) Epoch . . .	2.3
V.	Anthropolithic, or anthropozoic (quaternary) Epoch .	0.5
	Total ...	100.0

The relative durations of the five main epochs of th earth's organic history, are yet more clearly seen in th opposite Table (XIV.), in which the relative thicknesses o the strata systems deposited within these Epochs is repre sented on a scale corresponding to their actual depths.

This table shows that the period of the so-called Histor of the World forms but an inconsiderable span in compariso with the immeasurable duration of those earlier epochs durin which Man did not exist upon this planet. Even the gre Cænozoic Epoch, the so-called Tertiary Epoch, during whic the Placental Animals, the higher Mammals, develope includes but little more than two per cent. of the who enormous duration of the organic history of the world.[128]

And now before we turn to our proper phylogenet task; before, guided by our knowledge of ontogenetic fac and by the fundamental law of Biogeny, we attempt trace step by step the history of the palæontological ev lution of our animal ancestors, let us turn aside for a sho time into another and apparently very different and ve remote department of science, a general review of whi will make the solution of the difficult problems whi now rise before us very much easier. The science is th

TABLE XIV.

matic Survey of the Neptunian fossiliferous strata of the earth with eference to their relative sectional thickness (130,000 feet circa).

IV. Cænolithic Strata, circa 3000 feet.	Pliocene, Miocene, Eocene.
III. Mesolithic Strata. Deposits of the Secondary Epoch, circa 15,000 feet.	IX. Chalk System. ..... VIII. Jurassic System. ..... VII. Triassic System
II. Palæolithic Strata. Deposits of the Primary Epoch, circa 42,000 feet.	VI. Permian System. ..... V. Coal System. ..... IV. Devonian System.
I. Archilithic Strata. Deposits of the Primordial Epoch, circa 70,000 feet.	III. Silurian System, circa 22,000 feet. ..... II. Cambrian System, circa 18,000 feet. ..... I. Laurentian System, circa 30,000 feet.

of Comparative Philology. Ever since Darwin, by the theory of Natural Selection, infused new life into Biology, and raised the fundamental question of development in every branch of science, attention has frequently and from very different quarters been called to the remarkable parallelism, which exists between the evolution of the various human languages and the evolution of organic species. The comparison is quite justifiable and very instructive. Indeed it is hardly possible to find an analogy better adapted to throw a clear light on many obscure and difficult facts in the evolution of species, which is governed and directed by the same natural laws which guide the course of the evolution of language.

All philologists who have made any progress in their science, now unanimously agree that all human languages have developed slowly and by degrees from the simplest rudiments. On the other hand, the strange proposition which till thirty years ago was defended by eminent authorities, that language is a divine gift, is now universally rejected, or at best defended only by theologians and by people who have no conception of natural evolution. Such brilliant results have been attained in Comparative Philology that only one who is wilfully blind can fail to recognize the natural evolution of language. The latter is necessarily evident to the student of nature. For speech is a physiological function of the human organism, developing simultaneously with its special organs, the larynx and the tongue, and simultaneously with the functions of the brain. It is, therefore, quite natural that in the history of the evolution of languages, and in their whole system, we should find the same correlations as in the history of the evolution of organic species and in their whole system. The various

larger and smaller groups of speech-forms, which are distinguished in Comparative Philology as primitive languages, fundamental languages, parent languages, derived languages, dialects, patois, etc., correspond perfectly in their mode of development with the various larger and smaller groups of organisms classed in systems of Zoology and Botany as tribes, classes, orders, families, genera, species, and varieties of the animal and vegetable kingdoms. The relations between these various systematic groups, or categories, are in both cases identical; moreover, evolution follows the same course in one case as in the other. This instructive comparison was first elaborated by one of the most eminent of German philologists, one who, unfortunately, died prematurely—August Schleicher, not only a philologist but also a learned botanist. In his more important works, the Comparative Anatomy and evolutionary history of languages is treated by the same phylogenetic method which we employ in the Comparative Anatomy and evolutionary history of animal forms. He has especially applied this method to the Indo-Germanic family of languages; and in his little treatise on "The Darwinian Theory and the Science of Language" ("Die Darwin'sche Theorie und die Sprachwissenschaft"), he illustrated it by means of a synoptical pedigree of the Indo-Germanic family of languages.[129]

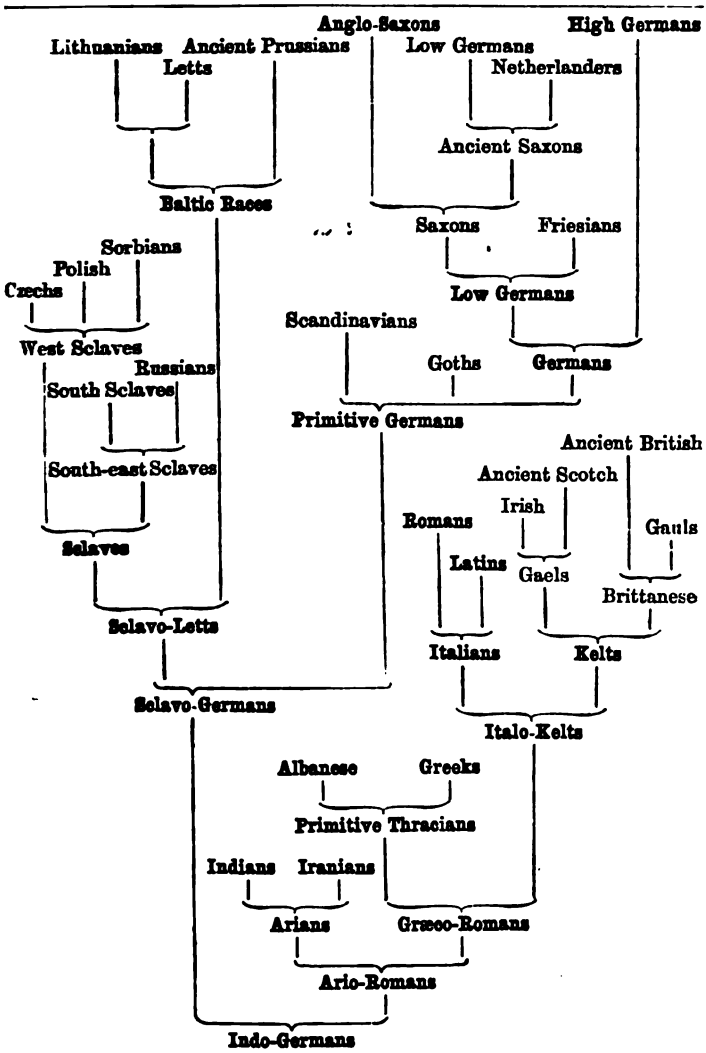
If the formation of the various branch languages which have developed from the common root of the primitive Indo-Germanic tongue is studied with the aid of this pedigree, a very clear idea of their Phylogeny will be acquired. At the same time it becomes evident how entirely analogous is the evolution of the greater and lesser groups of the Vertebrates, which have sprung from the one common root-

form of the primitive Vertebrates. The primitive Indo-Germanic root-tongue first separated into two chief stems: the Slavo-Germanic and the Ario-Romanic main-trunks. The Slavo-Germanic then branched into a primitive German and a primitive Slavo-Lettic tongue. Similarly, the Ario-Romanic split up into a primitive Arian and a primitive Græco-Romanic language (p. 23). If we continue our examination of this pedigree of the four primitive Indo-Germanic languages, we find that the primitive Germanic tongue divided into three chief branches—a Scandinavian, a Gothic, and a Teutonic branch. From the Teutonic branch proceeded, on the one hand, High German, and, on the other hand, Low German, to which latter belong the various Friesian, Saxon, and Low German dialects. Similarly, the Slavo-Lettic tongue developed first into a Baltic and a Slavonic language. From the Baltic spring the Lettic, Lithuanian, and Old Prussian dialects. The Slavic, on the other hand, give rise, in the South-east, to the Russian and the South Slavic dialects, and, in the West, to the Polish and Czech dialects.

Turning now to the other main stem of the Indo-Germanic languages and its branches—the primitive Ario-Romanic—it is found to develop with the same luxuriance. The primitive Græco-Romanic language gave rise, on the one hand, to the Thracian language (Albanian Greek), and on the other, to the Italo-Keltic. From the latter in turn sprung two divergent branches—in the South, the Italian branch (Romanic and Latin), and in the North, the Keltic, from which arose all the different British (Old British, Old Scottish, and Irish) and Gallic tongues. The numerous Iranian and Indian dialects branched out in the same way from the primitive Arian language.

TABLE XV.

Pedigree of the Indo-Germanic Languages.



A close study of this pedigree of the Indo-Germanic languages is, in many respects, of great interest. Comparative Philology, to which we are indebted for our knowledge of this subject, thus shows itself to be a true science—a *natural science.* It, indeed, long ago anticipated in its own province the phylogenetic method with the aid of which we now attain the highest results in Zoology and and in Botany. And here I cannot refrain from remarking how much to the advantage of our general culture it would be if the study of languages (which is undoubtedly one of the most powerful means of culture) were *comparatively* prosecuted; and if our cut and dried Philology were replaced by a living, many-sided, *comparative* study of languages. The latter stands in the same relation to the former as the living history of organic evolution does to the lifeless classification of species. How much deeper would the interest taken in the study of language by the students in our schools be, and how much more vivid would be the results if even the first elements of Comparative Philology were taught instead of the distasteful composition of Latin exercises in Ciceronian style!

I have entered with this detail into the "Comparative Anatomy" and the history of the evolution of languages, because it is unsurpassed as a means of illustrating the Phylogeny of organic species. We find that in structure and in development these primitive languages, parent languages, derived languages, and dialects, correspond exactly like the classes, orders, genera, and species of the animal kingdom. The "natural system" is in both cases phylogenetic. Just as Comparative Anatomy, Ontogeny, and Palæontology afford certain proof that all Vertebrates,

er extinct or extant, are descended from a common ral form, so does the comparative study of the dead iving Indo-Germanic language absolutely convince it all these languages have sprung from a common . This monophyletic view is unanimously adopted by guists of importance who have studied the question, ho are capable of passing a critical judgment upon it.[150] e point, however, to which I would specially call your ion in this comparison between the various branches, e one hand, of the Indo-Germanic language, and, on the of the vertebrate tribe, is that the direct descendants never be confounded with the collateral lines, nor the t with the extant forms. This mistake is often and results in the formation of erroneous notions of our opponents often take advantage in order to e the whole theory of descent. When, for instance, it d that human beings are descended from Apes, the from Semi-apes, and the Semi-apes from Pouched als (*Marsupialia*), very many people think only of the ar living species of these different mammalian orders, as are to be found stuffed in our museums. Now, our ents attribute this erroneous view to us, and, with craft than judgment, declare the thing impossible; or hey ask us as a physiological experiment to transform ngaroo into a Semi-ape, this into a Gorilla, and the la into a Man. Their demand is as childish as the ption on which it is founded is erroneous: for all extant forms have varied more or less from their non parent-form, and none of them are capable of pro- ng the same divergent posterity which were really uced thousands of years ago by that parent-form.[151]

There is no doubt that Man is descended from an exti mammalian form, which, if we could see it, we sho certainly class with the Apes. It is equally certain t this primitive Ape in turn descended from an unkno Semi-ape, and the latter from an extinct Pouched Anin But then it is beyond a doubt that it is only in respec essential internal structure, and on account of their simila in the distinctive anatomical characters of the order, that these extinct ancestral forms can be spoken of as memb of the yet extant mammalian orders. In external form generic and specific characters, they must have been more less—perhaps even greatly—different from all living rep sentatives of the orders to which they belonged. For must be accepted as a quite universal and natural fact phylogenetic evolution that the parent-forms themsel with their specific characters, became extinct at a more less distant period. Those extant forms which come nea to them, yet differ from them more or less, perhaps e very essentially. Hence in our phylogenetic researc and in our comparative view of the still living diverg descendants all we can undertake to do is to determ how far the latter depart from the parent-form. We n quite confidently assume that no single older parent-fo has reproduced itself without modification down to our ti

We find this same state of things on comparing vari extinct and living languages, which have sprung from common primitive tongue. If, from this point of view, examine the genealogical tree of the Indo-Germa languages, we may conclude, on *à priori* grounds, that the earlier primitive languages, fundamental languages, ancestral languages, from which the living dialects

nded in the first or second degree, have been extinct longer or shorter period. And this is the case. The Romanic and the Sclavo-Germanic tongues have long altogether extinct, as are also the primitive Arian and o-Romanic, the Sclavo-Lettic, and primitive Germanic ages. Some even of the languages descended from have also long been dead, and all those of the Indo-anic branch which are yet extant, are akin only in as they are divergent descendants of common parent-. Some have diverged from this ancestral form more, s less.

his easily demonstrable fact very well illustrates gous facts in the descent of vertebrate species. Phy-etic "Comparative Philology," as a powerful ally, sup-phylogenetic "Comparative Zoology." The former can, ver, adduce far more direct evidence than the latter, se the palæontological materials of Philology, the at monuments of extinct tongues, have been far better rved than the palæontological materials of Comparative gy, the fossil bones of vertebrates. The more these gous conditions are considered, the more convincing ir force.

'e shall presently find that we can trace back the logical line of Man, not only to the lower Mammals, ven to the Amphibia, to the shark-like Primitive Fishes, ven far below these, to the skull-less Vertebrates allied Amphioxus. It must be remembered this does not that the living Amphioxus, Shark, or Amphibian accu-represent the outward appearance of the parent-forms hich we speak. Still less does it mean that the hioxus, or the Shark of our day, or any extant species

Here arises another question: "Whence, in the beginning of the organic history of the earth, at the commencement of the Laurentian period, came the earliest Amœbæ?" To this there is but one reply. Like all one-celled organisms, the Amœbæ have originally developed only from the simplest organisms know to us, the Monera. These Monera, which we have already described, are also the simplest conceivable organisms. Their body has no definite form, and is but a particle of primitive slime (plasson)—a little mass of living albumen, performing all the essential functions of life, and everywhere met with as the material basis of life. This brings us to the last, or perhaps the first question in the history of evolution—the question as to the origin of the Monera. And this is the momentous question as to the prime origin of life—the question of spontaneous generation (*generatio spontanea* or *æquivoca*).

We have neither time, nor indeed have we any occasion, to discuss at length the weighty question of spontaneous generation. On this subject I must refer you to my "History of Creation," and, especially, to the second book of the *Generelle Morphologie*, and to the discussion on Monera and spontaneous generation in my "Studien über Moneren und andere Protista."[182] I have there stated my own views on this important subject in very great detail. Here I will only say a few words on the obscure question as to the first origin of life, and will answer it so far as it concerns our radical conception of the history of organic evolution. In the definite, limited sense in which I maintain spontaneous generation (*generatio spontanea*) and assume it as a necessary hypothesis in explanation of the first beginning of life upon

earth, it merely implies the origin of Monera from rganic carbon compounds. When animated bodies first peared on our planet, previously without life, there must, the first place, have been formed, by a process purely mical, from purely inorganic carbon combinations, that y complex nitrogenized carbon compound which we call sson, or "primitive slime," and which is the oldest material stance in which all vital activities are embodied. In lowest depths of the sea such homogeneous amorphous toplasm probably still lives, in its simplest character, under name of Bathybius.[137] Each individual living particle this structureless mass is called a Moneron. The oldest nera originated in the sea by spontaneous generation, t as crystals form in the matrix. This assumption is uired by the demand of the human understanding for sality. For when, on the one hand, we reflect that the ole inorganic history of the earth proceeds in accordance th mechanical laws and without any intervention by ative power, and when, on the other hand, we consider t the entire organic history of the world is also de- mined by similar mechanical laws; when we see that no ernatural interference by a creative power is needed for production of the various organisms, then it is certainly te inconsistent to assume such supernatural creative erference for the first production of life upon our globe. all events we, as investigators of nature, are bound least to attempt a natural explanation.

At present, the much agitated question of spontaneous neration appears very intricate, because a large number very different, and in part quite absurd, conceptions are luded under the term "spontaneous generation," and

because some have supposed that the problem could be solved by means of the crudest experiments. The doctrine of spontaneous generation cannot be experimentally refuted. For each experiment with a negative result merely proves that under the conditions (always very artificial) supplied by us, no organism has been produced from inorganic combinations. Neither can the theory of spontaneous generation be experimentally proved unless great difficulties are overcome; and even if in our own time Monera were produced daily by spontaneous generation—as is very possible—yet the absolute empiric proof of this fact would be extremely difficult—indeed, in most cases impossible. He, however, who does not assume a spontaneous generation of Moners, in the sense here indicated, to explain the first origin of life upon our earth, has no other resource but to believe in a supernatural miracle; and this, in fact, is the questionable standpoint still taken by many so-called "exact naturalists," who thus renounce their own reason.

Sir William Thomson has indeed tried to avoid the necessary hypothesis of spontaneous generation by assuming that the organic inhabitants of our earth originally descended from germs which proceeded from the inhabitants of other planets, and which, with fragments of the latter, with meteorites, accidentally fell on to the earth. This hypothesis has met with much applause, and was even supported by Helmholtz. Friederich Zoellner, an acute physicist, has, however, refuted it in his excellent natural-philosophical work "Ueber die Natur der Cometen," a critical book containing most valuable contributions to the history and theory of knowledge.[127] Zoellner has plainly shown that the hypothesis is unscientific in two respects—

rstly, in point of logic, and secondly, in its scientific tenor p. xxvi). At the same time he rightly shows that the ypothesis of spontaneous generation, in the sense which e have defined, is the "condition necessary to the conceiv-bility of nature in accordance with the laws of causality."

In conclusion, I repeat, with emphasis, that it is only in he case of Monera—of structureless organisms without rgans—that we can assume the hypothesis of spontaneous eneration. Every differentiated organism, every organism omposed of organs, can only have originated from an ndifferentiated lower organism by differentiation of its arts, and consequently by Phylogeny. Hence, even in the roduction of the simplest cell we must not assume the pro-ess of spontaneous generation. For even the simplest cell onsists of at least two distinct constituent parts; the nner and firmer kernel (nucleus), and the outer and ofter cell-substance or protoplasm. These two distinct arts can only have come into being by differentiation of the homogeneous plasson of a moneron and of a cytod. It is for this very reason that the natural history of Monera is of the highest interest; for it alone can remove the principal difficulties which beset the question of spontaneous genera-tion. The extant Monera do afford us organless and struc-tureless organisms, such as must have originated by spon-taneous generation at the first beginning of organic life upon the earth.[133]

CHAPTER XVI.

THE ANCESTRY OF MAN.

I. From the Monera to the Gastræa.

Relation of the General Inductive Law of the Theory of Descent t
Special Deductive Laws of the Hypotheses of Descent.—Incomplet
of the Three Great Records of Creation: Palæontology, Ontogeny
Comparative Anatomy.—Unequal Certainty of the Various S
Hypotheses of Descent.—The Ancestral Line of Men in Twent
Stages: Eight Invertebrate and Fourteen Vertebrate Ancestors.—I
bution of these Twenty-two Parent-forms in the Five Main Divisi
the Organic History of the Earth.—First Ancestral Stage: Mon
The Structureless and Homogeneous Plasson of the Monera.—Dif
tiation of the Plasson into Nucleus, and the Protoplasm of the C
Cytods and Cells as Two Different Plastid-forms.—Vital Phen
of Monera.—Organisms without Organs.—Second Ancestral S
Amœbæ.—One-celled Primitive Animals of the Simplest and mo
differentiated Nature.—The Amœboid Egg-cells.—The Egg is Olde
the Hen.—Third Ancestral Stage: Syn-Amœba, Ontogenetically
duced in the Morula.—A Community of Homogeneous Amœboid C
Fourth Ancestral Stage: Planæa, Ontogenetically reproduced i
Blastula or Planula.—Fifth Ancestral Stage: Gastræa, Ontogene
reproduced in the Gastrula and the Two-layered Germ-disc.—Ori
the Gastræa by Inversion (*invaginatio*) of the Planæa.—Haliph
and Gastrophysema.—Extant Gastræads.

"Now, very probably, if the course of evolution proves to be so simple, it will be thought that the whole matter is self-evident, and research is hardly required to establish it. But the story of Columbu the egg is daily repeated; and it is necessary to perform the exper

one's self. How slowly progress is made in the knowledge even of self-dent matters, especially when respectable authorities disagree, I myself e experienced sufficiently."—KARL ERNST BAER (1828).

IDED by the fundamental law of Biogeny and by the re records of creation, we now turn to the interesting k of examining the animal parent-forms of the human e in their proper sequence. To ensure accuracy, we st first become acquainted with the various mental erations which we shall apply in this natural-philosophical earch. These operations are partly of an inductive, rtly of a deductive nature; partly conclusions from merous particular experiences to a general law; partly elusions from this general law back to particular ex-iences.

Tribal history as a whole is an inductive science; for whole theory of descent, as an indispensable and most ential part of the whole theory of evolution, is entirely nded on inductions. From all the biological incidents in nt life, in animal life, and in human life, we have derived certain inductive conception that the whole of the or-nic inhabitants of our globe originated in accordance with a single law of evolution. To this law of evolution, La-rck, Darwin, and their successors gave definite form in theory of descent. All the interesting phenomena ex-ited by Ontogeny, Palæontology, Comparative Anatomy, steleology, Chorology, the Œkology of organisms, all the portant general laws, which we infer from multitudinous enomena of these different sciences, and which are most imately connected together, are the broad inductive ta from which is drawn the most extensive inductive w of Biology. Because the innate connection between all

these infinitely various groups of phenomena in thes
ferent departments becomes explicable and comprehe
solely through the theory of descent, therefore this t
of evolution must be regarded as an extensive indu
law. If we now really apply this inductive law, and
its help seek to discover the descent of individual or
species, we must necessarily form phylogenetic hypot
which are of an essentially deductive nature, and whic
inferences from the general theory of descent back to
vidual particular cases. These special deductive conclu
are, however, in accordance with the inexorable la
Logic, as justifiable, as necessary, and as indispensab
our department of knowledge as the general indu
conclusions of which the whole theory of evolutic
formed. The doctrine of the animal parent-forms of
kind is also a special deductive law of this kind, whi
the logical conclusion from the general inductive law o
theory of descent.[134]

As is now very generally acknowledged, both by
adherents of and the opponents of the theory of des
the choice, in the matter of the origin of the human
lies between two radically different assumptions: We
either accustom ourselves to the idea that all the va
species of animals and plants, Man also included,
ginated independently of each other by the superna
process of a divine "creation," which as such is ent
removed from the sphere of scientific observation—o
are compelled to accept the theory of descent in its enti
and trace the human race, equally with the various an
and plant species, from an entirely simple primæval pa
form. Between these two assumptions there is no t

course. Either a blind belief in creation, or a scientific theory of evolution. By assuming the latter, and this is the only possible natural-scientific conception of the universe, we are enabled, with the help of Comparative Anatomy and Ontogeny, to recognize the human ancestral line with a certain approximate degree of certainty, just as is more or less the case with respect to all other organisms. Our previous study of the Comparative Anatomy and Ontogeny of Man, and of other Vertebrates, has made it quite clear that we must first seek the pedigree of mankind in that of the vertebrate tribe. There can be no doubt that (if the theory of descent is correct) Man has developed as a true Vertebrate, and that he originated from one and the same common parent-form with all other Vertebrates. This special deduction must be regarded as quite certain, correctness of the inductive law of the theory of descent being of course first granted. No single adherent of the latter can raise a doubt about this important deductive conclusion. We can, moreover, name a series of different forms of the vertebrate tribe, which may be safely regarded as the representatives of different successive phylogenetic stages of evolution, or as different members of the human ancestral line. We can also prove with equal certainty that the vertebrate tribe as a whole originated from a group of low invertebrate animal forms; and among these we can again with more or less certainty recognize a series of members of the ancestral chain.

We must, however, at once expressly say that the certainty of the different hypotheses of descent, which are founded entirely on special deductive inferences, is very unequal. Several of these conclusions are already fully

established; others, on the contrary, are most doubtful; in yet others, it depends upon the subjective proportion of the knowledge of the naturalist and on his capability of drawing conclusions, what degree of probability he will accord to them. It is, at all events, necessary thoroughly to distinguish between the *absolute* certainty of the general (inductive) theory of descent, and the *relative* certainty of the special (deductive) hypothesis of descent. We can never in any case prove the whole ancestral line of ancestors of an organism with the same certainty with which we regard the theory of descent as the only scientific explanation of the organic forms. On the contrary, the special proof of all separate parent-forms must always remain more or less incomplete and hypothetical. That is quite natural. For all the records of creation upon which we rely are in a great measure incomplete, and will always remain incomplete; just as in the case of Comparative Philology.

Above all, Palæontology, the most ancient of all records of creation, is in the highest degree incomplete. We know that all the petrifications with which we are acquainted form but an insignificantly small fragment of the whole number of animal forms and plant forms which have ever existed. For each extinct species obtained by us in a petrified condition, there are at least a hundred, probably thousands of extinct species which have left no trace of their existence. This extreme and most deplorable defectiveness of the palæontological record of creation, upon which it is impossible to insist too strongly, is very easily accounted for. The very conditions under which organic remains become petrified necessitate it. It is also partly explicable as the result of

imperfect knowledge in this department. It must be membered, that far the greater proportion of the rock ata which constitute the mountain masses of the surface the earth is not yet unfolded to us. Of the count- s petrifications which are hidden in the huge moun- in chains of Asia and Africa, we know but a few small mples. Part of Europe and of North America has alone en more minutely explored. The whole of the petri- ctions accurately known and in our collections do not nount to a hundredth part of those which really exist in e crust of the earth. In this respect we may, therefore, pect a rich harvest of discoveries in the future. But, in ite of this, the palæontological record of creation (for asons which I have amply explained in Chapter XV. of y "Natural History of Creation") will always remain tremely incomplete.

Not less incomplete is the second, most important record creation, that of Ontogeny. For the Phylogeny of the lividual it is the most important of all. Yet, it also has great defects, and often leaves us in the lurch. In this tter, we must distinguish quite clearly between palin- netic and kenogenetic phenomena, between the original, herited evolution and the later, vitiated evolution. We st never forget that the laws of abridged and vitiated redity frequently disguise the original course of evolution yond recognition. The reproduction of the Phylogeny the Ontogeny is but rarely tolerably complete. The rliest and most important stages of germ-history are ually the most abridged and compressed. The youthful olutionary forms have in turn often adapted themselves new conditions, and have thus been modified. The

struggle for existence has excited an equally strong modifying influence upon the various independent and yet undeveloped young forms, as upon the developed and mature forms. Therefore, in the Ontogeny of the higher animal forms, the Phylogeny has been very greatly limited by Kenogenesis; as a rule, only a blurred and much vitiated picture of the original course of evolution of their ancestors now lies before us in the Ontogeny. Only with great precaution and judgment dare we infer the tribal history directly from the germ-history. Moreover, the germ-history itself is known to us only in the case of very few species.

Lastly, the highly important record of creation afforded by Comparative Anatomy is unfortunately very incomplete, and for the simple reason, that the number of extant animal species forms but a very small fragment of the whole number of different animal forms that have existed from the beginning of the organic history of the world to the present time. The total sum of the latter may safely be estimated at several millions. The number of those animals the organization of which has at present been investigated by Comparative Anatomy is very small in proportion. The more extended investigations of the future will, here also, open up unexpected treasures.

In view of this evident and natural incompleteness of the most important records of creation, we must of course take good care, in the tribal history of Man, not to lay too great weight on single known animal forms, nor with equal certainty to consider all the stages of evolution which come under our consideration, as parent-forms. On the contrary, in hypothetically arranging our ancestral line, we must take good care to remember that the single hypothetical

arent-forms are of very diverse values in relation to the rtainty of our knowledge. From the few remarks which, hile speaking of the Ontogeny, we made as to the corre-onding phylogenetic forms, it will have been understood at some germ-forms may with certainty be regarded as eproductions of corresponding parent-forms. We recog-ized the human egg-cell and the parent-cell which results om the impregnation of the latter as the first and most nportant form of this kind.

From the weighty fact that the egg of the human being, ike the egg of all other animals, is a simple cell, it may be uite certainly inferred that a one-celled parent-form once xisted, from which all the many-celled animals, Man in-luded, developed.

A second very significant germ-form, which evidently eproduces a primæval parent-form, is the germ-vesicle (*Blastula*), a simple hollow sphere, the wall of which con-sists of a single cell-stratum. A third extremely import-ant form in germ-history, which may be quite safely and directly referred back to the tribal history, is the true Gas-trula. This most interesting larval form already exhibits the animal body composed of two germ-layers, and fur-nished with the fundamental primitive organ, the intestinal canal. Now, as the same two-layered germ-condition, with the primitive rudiment of the intestinal canal, is common to all the other animal tribes (with the single exception of the Primitive Animals, *Protozoa*), we may certainly from this infer a common parent-form of similar construction to the Gastrula, the Gastræa. Equally important in their bearing on the Phylogeny of Man, are the very important ontoge-netical form conditions which correspond to certain Worms,

Skull-less Animals (*Acrania*), Fishes, etc., etc. On the other hand, between these quite certain and most valuable phylogenetic points, great gaps in our knowledge unfortunately exist, with which we shall again and again meet, and which are satisfactorily explained by reasons which have already been named, especially by the incompleteness of Palæontology, of Comparative Anatomy, and Ontogeny.

In the first attempts to construct the human ancestral line, which I made in my *Generelle Morphologie*, and in the "Natural History of Creation," I arranged first ten, and, later, twenty-two different animal forms, which, with more or less certainty, may be regarded as the animal ancestors of the human race, and which must be looked upon as in a sense the most important stages of evolution in the long evolutionary series from the one-celled organisms up to Man.[185] Of these twenty to twenty-two animal forms, about eight fall within the older division of the Invertebrates, while twelve to fourteen belong to the more recent Vertebrate division. How these twenty-two most important parent-forms in the human ancestral line are distributed through the five main periods of the organic history of the earth, is shown in the following Table (XVI.). At least half of these twenty-two stages of evolution (that is, the eleven oldest ancestral forms) are found within the Archilithic Epoch, within that first main period of the organic history of the earth, which includes the larger half of the latter, and during which probably only aquatic organisms existed. The eleven remaining parent-forms fall within the four remaining main Epochs: three within the Palæolithic Epoch, three within the Mesolithic Epoch, and four within the Cænolithic Epoch. In the last, the Anthropolithic Age, Man already existed.

If we would now undertake the difficult attempt to discover the phylogenetic course of evolution of these twenty-two human ancestral stages from the very commencement of life, and if we venture to lift the dark veil which covers the oldest secrets of the organic history of the earth, we must undoubtedly seek the first beginning of life among those wonderful living beings which, under the name of Monera, we have already frequently pointed out as the simplest known organisms. They are, at the same time, the simplest conceivable organisms; for their entire body, in its fully developed and freely moving condition, consists merely of a small piece of structureless primitive slime or plasson, of a small fragment of that extraordinarily important nitrogenous carbon compound, which is now universally esteemed the most important material substratum of all the active phenomena of life. The experiences of the last ten years particularly have convinced us with more and more certainty that wherever a natural body exhibits the active phenomena of life, nutrition, propagation, spontaneous movement, and sensation, a nitrogenous carbon compound, belonging to the chemical group of albuminous bodies, is always active, and represents the material substance through which these vital activities are effected. Whether, in a monistic sense, we conceive the function as the direct effect of the formed material substance, or, in a dualistic sense, we regard "Matter and Force" as distinct, it is at least certain that, hitherto, no living organism has been observed in which the exercise of vital activities was not inseparably connected with a plasson-body. In the Monera, the simplest conceivable organisms, the whole body consists merely of plasson, corresponding to the "primitive slime" of earlier natural philosophy.

TABLE XVI.

Systematic Survey of the most Important Stages in the Animal Ancestral Line of Man.

M N = Boundary between the Invertebrate and the Vertebrate Ancestors.

Epochs of the Organic History of the Earth.	*Geological Periods of the Organic History of the Earth.*	*Animal Ancestral Stages of Man.*	*Nearest Living Relatives of the Ancestral Stages.*
I. Archilithic or Primordial Epoch	1. Laurentian Period 2. Cambrian Period 3. Silurian Period	1. Monera (*Monera*)	Bathybius
		2. Oldest Amœbæ	Protamœba Simple Amœbæ (*Autamœba*)
		3. Amœboid Societies (*Synamœbia*)	Morula larvæ
		4. Ciliated planulæ (*Planræadæ*)	Blastula larvæ
		5. Primitive Intestinal animals (*Gastræadæ*)	Gastrula larvæ
		6. Primitive Worms (*Archelminthes*)	Gliding Worms (*Turbellaria*)
		7. Soft-worms (*Scolecida*)	? Between the gliding worms and the Sea-squirts
		8. Chorda animals (*Chordonia*)	Sea-squirts (*Ascidia*) (*Appendicularia*)
		M ..... N	
		9. Skull-less animals (*Acrania*)	Lancelets (*Amphioxi*)
		10. Round-mouths (*Cyclostomi*)	Lampreys (*Petromyzonia*)
		11. Primitive Fishes (*Selachii*)	Sharks (*Squalacei*)
II. Palæolithic or Primary Epoch	4. Devonian Period 5. Coal Period 6. Permian Period	12. Salamander Fishes (*Dipneusta*)	Mud fish (*Protoptera*)
		13. Gilled Amphibia (*Sozobranchia*)	Siren (*Proteus*) and Axolotl (*Siredon*)
		14. Tailed Amphibia (*Sozura*)	Water-newt (*Triton*)
III. Mesolithic or Secondary Epoch	7. Triassic Period 8. Jurassic Period 9. Chalk Period	15. Primitive Amniota (*Protamnia*)	? Between Tailed Amphibians and Beaked animals
		16. Primitive Mammals (*Promammalia*)	Beaked animals (*Monotrema*)
		17. Pouched Animals (*Marsupialia*)	Pouched Rats (*Didelphyes*)
IV. Cænolithic or Tertiary Epoch	10. Eocene Period 11. Miocene Period 12. Pliocene Period	18. Semi-Apes (*Prosimia*)	Lori (*Stenops*) Maki (*Lemur*)
		19. Tailed Narrow-nosed Apes	Nose Apes Holy Apes
		20. Men-like Apes or Tail-less Narrow-nosed Apes.	Gorilla, Chimpanzee, Orang, Gibbon
		21. Speechless Men or Ape-like Men	Cretins or Microcephali
V. Quaternary Epoch	13. Diluvial Period 14. Alluvial Period	22. Men capable of speech	Australians and Papuans

The soft slimelike plasson-substance of the body of the Moneron is commonly called "*protoplasma*," and identified with the cell-substance of ordinary animal and plant cells. As, however, Eduard van Beneden, in his excellent work upon the Gregarinæ, first clearly pointed out, we must, strictly speaking, distinguish thoroughly between the plasson of cytods and the protoplasm of cells. This distinction is of special importance in its bearing on the history of evolution. As was before incidentally mentioned, we must assume two different stages of evolution in those elementary organisms, which, as formative particles or plastids, represent organic individuality of the first order. The older and lower stage is that of the cytods, in which the whole body consists of but one kind of albuminous substance, of the simplest plasson or formative material. The more recent and higher stage is that of cells, in which a separation or differentiation of the original plasson into two different kinds of albuminous substances, into the inner cell-kernel (*nucleus*), and the outer cell-substance (*protoplasma*), has already taken place.

The Monera are the simplest permanent cytods. Their entire body consists merely of soft, structureless plasson. However thoroughly we examine them with the help of the most delicate chemical reagents and the strongest optical instruments, we yet find that all the parts are completely homogeneous. These Monera are, therefore, in the strictest sense of the word, "organisms without organs;" or even, in a strictly philosophical sense, they might not even be called "organisms," since they possess no organs, since they are not composed of various particles. They can only be called organisms, in so far as they are capable of exercising the

organic phenomena of life, of nutrition, reproduction, sensation, and movement. If we tried to construct, *à priori*, the simplest conceivable organism, we should always be compelled to fall back upon such a Monera.

Although in all real Monera the body consists merely of such a small living piece of plasson, yet, among the Monera, which have been observed in the sea and in fresh water, we have been able to distinguish several different genera and species, varying in the mode in which their tiny bodies move and reproduce. In the ways in which movement is accomplished very noticeable differences exist.

FIG. 163.—A Moneron (*Protamœba*) in the act of reproduction: *A*, the whole Moneron, which moves, like the ordinary Amœba, by means of variable processes; *B*, a contraction round its circumference parts it into two halves; *C*, the two halves separate, and each now forms an independent individual (much enlarged).

In some Monera, especially in the Protamœba (Fig. 163), the formless body, during its movements, invariably develops only a few, short, and blunt processes, which project like fingers, slowly altering their form and size, but never branching. In other Monera, on the other hand (*e.g.* *Protomyxa*, *Myxastrum*), very numerous, long, fine, and generally thread-like processes arise from the surface of the movable body, and these branch irregularly, inter-

ng their free moving ends, so as to form a net. Huge s of such slime-nets crawl upon the deepest bottom sea (*Bathybius*, Fig. 164). Within these soft slime-plasson-nets slow currents continually pass. Such a ron may be fed with finely pulverized colouring r (for instance, carmine or indigo powder), if this er is scattered in the drop of water under the micro-, in which the Moneron is contained. The grains louring matter at first adhere to the surface of the body, and then gradually penetrate, and are driven in irregular directions. The separate smallest par-, or molecules, of the Moneron-body, called "plas-s,"[136] displace each other, change their relative ons, and thus effect a change in the position of the bed particles of colouring matter. This change of ion, at the same time, proves positively that a hidden ite structure does not exist. It might be argued that Monera are not really structureless, but that their nization is so minute that, in consequence of the in-nate power of our magnifying glasses, it is invisible. objection is, however, invalid, for by the experiment eding, we can, at any moment, prove the entrance of gn, formed, small bodies into the different parts of the of the Moneron, and that these are irregularly driven t in all directions. At the same time we see that the geable network of threads, formed by the branching e protoplasmic threads and the coalescence of the con-t branches, alter their configuration every moment; as has long been known to occur in the thread-nets e protoplasm in the interior of the plant-cells. The era are, therefore, really homogeneous and structureless;

each part of the body is every other part. Each part can absorb and digest nourishment; each part is excitable and sensitive; each part can move itself independently; and lastly, each part is capable of reproduction and regeneration.

The reproduction of Monera always occurs asexually. In the Protamœba (Fig. 163), each individual, after it has grown to a certain size, simply separates into two pieces. Round the circumference of the body a contraction arises, as in cell-division. The connection between the two halves continually becomes more slender (*B*), and finally parts in the middle. Thus, in the simplest possible way, two new individuals proceed by self-division from one quite simple individual (*C*). Other Monera, after they have grown to a certain size, gather themselves together into a spherical form. The globular protoplasmic body exudes a jelly-like protecting envelope, and a breaking-up of the whole plasson-ball takes place within this covering; it breaks either into four pieces (*Vampyrella*), or into a large number of smaller globules (*Protomonas, Protomyxa;* cf. Plate I. in the "Natural History of Creation"). After a time, these globules begin to move, split the integument by their movement, and emerge; after which they float about by means of a long, thin, thread-shaped process. Each again passes by simple growth into the mature form. Thus, it is possible to distinguish different genera and species of Monera, on one hand, by the form of the different processes of the body, and, on the other hand, by the different kind and manner of reproduction. In the appendix to my monograph of the Monera I enumerated eight genera and sixteen species ("Biol. Studien," vol. i. p. 182). The

st remarkable of all Monera is the Bathybius, which was covered by Huxley in 1868 (Fig. 164). This wonderful neron lives in the deepest parts of the sea, especially in

FIG. 164.—Bathybius Hæckelii (Huxley). A small piece of the formless continually changing plasson-net of this Moneron from the Atlantic n.

Atlantic Ocean, and in places covers the whole floor he sea in such masses, that the fine mud on the latter ists, in great measure, of living slime. The protoplasm these formless nets does not seem differentiated at each little piece is capable of forming an individual. active amœboid movements of these formless pieces of son, which were first observed by the English zoologists penter and Wyville Thomson, have recently been again rved by the German Arctic voyager, Emil Bessels, in Bathybius of the coast of Greenland.[137]

The origin and importance of these huge masses of ng, formless plasson-bodies in the lowest depths of the

sea, raises many different inquiries and thoughts. Spor taneous generation, especially, is naturally suggested by th Bathybius. We have already found that, for the origin (first Monera upon our globe, the assumption of spontaneou generation is a necessary hypothesis. We shall be all th more inclined to confirm it now that, in the Monera, we hav recognized those simplest organisms, the origin of whic by spontaneous generation, in the present condition of ou science, no longer involves very great difficulties. For th Monera actually stand on the very boundary betwee organic and inorganic natural bodies.[188]

Next to the simple cytod-bodies of the Monera, as th second ancestral stage in the human pedigree (as in that o all other animals), comes the simple cell, that most undifferen tiated cell-form, which, at the present time, still leads a independent solitary life, as the Amœba. For the first an oldest process of organic differentiation, which affected th homogeneous and structureless plasson-body of the Monen caused the separation of the latter into two different sul stances; an inner firmer substance, the kernel, or *nucleu* and an outer, softer substance, the cell-substance, (*protoplasma.* By this extremely important separative pr cess, by the differentiation of the plasson into nucleus an protoplasm, the organized cell originated from the structur less cytod, the nucleolated from the non-nucleolated plasti That the cells which first appeared upon the earth origi ated in this manner, by the differentiation of the Monera, a conception which in the present condition of histologic knowledge seems quite allowable; for we can even y directly observe this oldest histological process of diffe entiation in Ontogeny. It will be remembered that in tl

egg-cell of animals, either before or after fertilization, the original kernel disappeared. We explained this phenomenon as a reversion or atavism, and assumed that the egg-cell, in accordance with the law of latent heredity, first falls back into the kernel-less, cytod stage (Fig. 165). It is only after fertilization is accomplished that a new cell-kernel arises in this cytod, which thus becomes the parent-cell (*Cytula*, Fig. 166). The transitory kernel-less cytod-condition, intermediate between the egg-cell and the parent-cell, is an interesting germ-form, because, in accordance with the fundamental law of Biogeny, it reproduces the original, oldest parent-form of the Moneron; we therefore call it the Monerula. (Cf. vol. i. pp. 178–183.)

FIG. 165.—Monerula of Mammal (Rabbit). The fertilized egg-cell after the loss of the nucleus is a simple ball of protoplasm (*d*). The outer covering of the latter is formed by the modified *zona pellucida* (*z*) together with a mucous layer (*h*) secreted on to the outside of the latter. In this a few sperm-cells are still visible (*s*).

FIG. 166.—Parent-cell (*Cytula*) of a Mammal (Rabbit): *k*, parent-kernel; *n*, *nucleolus* of the latter; *p*, protoplasm of the parent-cell; *z*, modified *zona pellucida*; *s*, sperm-cells; *h*, outer albuminous covering.

We have already explained the one-celled germ-form, which we see in the original egg-cell and the parent-cell which is originated by the fertilization of the egg-cell, as the reproduction of a one-celled parent-form, to which we ascribed the organization of an Amœba (cf. Chap. VI.). For the Amœba, as it yet lives widely distributed in the fresh and salt waters of the globe, must be regarded as the most undifferentiated and most original of the various one-celled Primitive Animals. As the immature primitive egg-cells (which as "primitive eggs" or *Protova* are found in the ovary of animals) are indistinguishable from ordinary Amœbæ, we are justified in pointing to the Amœba as the one-celled phylogenetic form, which, in accordance with the fundamental law of Biogeny, is at the present time yet reproduced in the ontogenetic primitive condition of the "Amœboid egg-cell." As evidence of the striking correspondence of the two cells, it was incidentally mentioned that in the case of some Sponges the real eggs of these animals were formerly described as parasitic Amœbæ. Large one-celled Amœba-like organisms were seen creeping about in the interior of the Sponge, and were mistaken for parasites. It was only afterwards that it was discovered that these "parasitic Amœbæ" (Fig. 168) are really the eggs of the Sponge, from which the young Sponges develop. These egg-cells of the Sponge are, however, so like the true common Amœbæ (Fig. 167) in size and structure, in the nature of their nuclei and in the characteristic form of movement of their continually changing false-feet (*pseudopodia*), that, unless their source is known, it is impossible to distinguish them.

This phylogenetic explanation of the egg-cell and its

reference to the primæval ancestral form of the Amœba, directly enables us to give a definite answer to the old humorous riddle: Which was first, the egg or the hen? We can

FIG. 167.—A crawling Amœba (much enlarged). The whole organism has the form-value of a simple naked cell and moves about by means of changeable processes, which are extended from the protoplasmic body and again drawn in. In the inside is the bright-coloured, roundish cell-kernel or nucleus.

FIG. 168.—Egg-cell of a Chalk-Sponge (*Olynthus*). The egg-cell creeps about in the body of the Sponge by extending variable processes, like those of the ordinary Amœba.

now very simply answer this Sphinx-question, with which our opponents try to shake or even to refute the Theory of Evolution. The egg existed much earlier than the hen. Of course it did not exist in the form of a bird's egg, but as an undifferentiated amœboid cell of the simplest form. The egg existed independently during thousands of years as a simplest one-celled organism, as the Amœba. It was only after the descendants of these one-celled Primitive Animals had developed into many-celled animal forms, and after these had sexually differentiated, that the egg, in the present physiological sense of the word, originated from the amœ-

boid cell. Even then, the egg was first a Gastræa-egg, then a Worm-egg, then an Acrania-egg, then a Fish-egg, an Amphibian-egg, a Reptile-egg, and lastly, a Bird-egg. The egg of the Bird, as it now is, is a most complex historical product, the result of countless processes of heredity, which have occurred in the course of many millions of years.[139]

The fact that this primitive egg-form, as it first appears in the ovary of the most dissimilar animals, is always of one form, an undifferentiated cell, of the simplest amœboid character, has already been pointed out as an especially important phenomenon. In this earliest young conditi[illegible] immediately after the individual egg-cell has originated [illegible] consequence of a separation of the cells of the mater[illegible] ovary, no essential difference is recognizable in the egg-c[illegible] of the most dissimilar animals. (Cf. Fig. 10, vol. i. p. 134.) [illegible] is not till later, when the primitive egg-cells, or the primiti[illegible] eggs (*protova*), have absorbed different kinds of nutritive yelk, and have surrounded themselves with variously formed coverings, and in other ways differentiated—it is not till they have in this way changed into after-eggs (*metova*), that those of different classes of animals can usually be distinguished. These peculiarities of the developed after-egg, the mature egg, are naturally to be considered as only secondarily acquired, by adaptation to the different conditions of existence both of the egg itself and of the animal which forms the egg.

The two first and oldest ancestral forms of the human race, which we have now considered, the Moneron and the Amœba, are, considered from a morphological point of view, simple organisms and individuals of the first order, Plastids. All subsequent stages in the ancestral chain are, on the

other hand, compound organisms or individuals of higher order—social aggregations of a number of cells. The earliest of these, which, under the name of Synamœbæ, we must rank as the third stage of our pedigree, are quite simple societies of all homogeneous undifferentiated cells; amœboid communities. To be certain as to their nature and origin, we need only trace the ontogenetic product of the parent-cell step by step. After the cytula (Fig. 166) has originated, by the re-formation of a cell-kernel, from

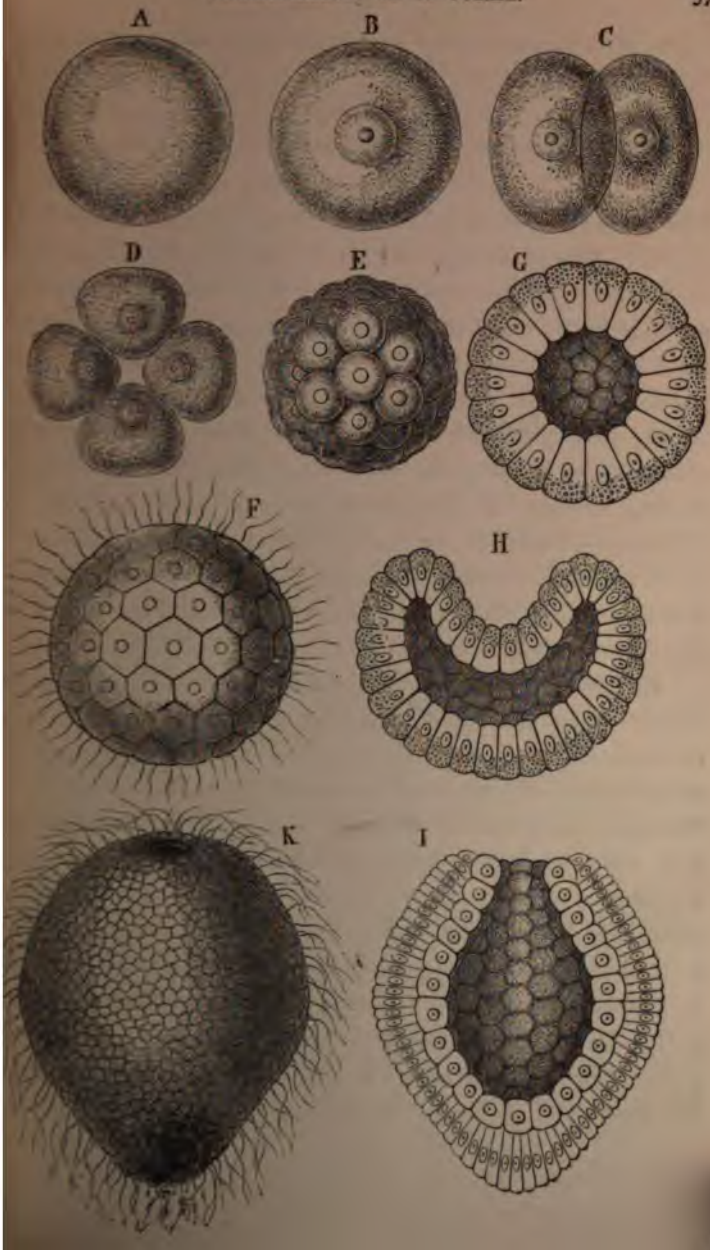
FIG. 169.—Original or primordial egg-cleavage. The parent-cell, or cytula, which resulted from the fertilization of the egg-cell, first breaks up, by a continuous and regular process of division, into two cells (*A*), then into four (*B*), then into eight (*C*), and, lastly, into very numerous cleavage-cells (*D*).

the Morula (Fig. 165), the parent-cell breaks up, by repeated division, into numerous cells. We have already minutely examined this important process of egg-cleavage, and have found that all the various modes of the latter are modifications of a single mode, that of original or primordial cleavage. (Cf. Chap. VIII., p. 188.) In the Vertebrate line this palingenetic form of egg-cleavage has been accurately re-

FIG. 170.—Mulberry-germ, or morula.

tained to the present time only by the Amphioxus, while all other Vertebrates have assumed a modified kenogenetic form of cleavage. (Cf. Table III., vol. i. p. 241.) The latter certainly originated at a later period than the former, and the egg-cleavage of the Amphioxus is, therefore, extremely interesting (vol. i. p. 442). In this the parent-cell first parts into two similar cells, the two first cleavage-cells (Fig. 169, *A*). From these, by continuous division, arise 4, 8, 16, 32, 64 cells, etc., etc. (Fig. 169). The final result of this primordial cleavage was, we found, the formation of a globular mass of cells, which was entirely composed of homogeneous, undifferentiated cells of the simplest character (Figs. 170, and 171, *E*). On account of the resemblance which this globular mass of cells bears to a mulberry or blackberry, we called it the "mulberry-germ," or *morula*.

This "morula" evidently at the present day shows us the many-celled animal body in the same entirely simple primitive condition in which, in the earlier Laurentian primitive epoch, it first originated from the one-celled amœboid primitive animal form. The morula reproduces, in accordance with the fundamental law of Biogeny, the ancestral form of the Synamœba. For the first cell-communities, which then formed, and which laid the first foundation of the higher many-celled animal body, must have consisted entirely of homogeneous and quite simple amœboid cells. The earliest Amœbæ lived isolated hermit lives, and the amœboid cells, which originated from the division of these one-celled organisms, must also have long lived isolated and self-dependent lives. Gradually, however, by the side of these one-celled Primitive Animals, small amœboid communities arose, owing to the fact that the


A
B
C
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I

Various kinds of Primitive Animals, which yet
both in the sea and in fresh water, are formed essent
like the blastula, and which, in a certain sense, may be
sidered as permanent or persistent blastula-forms, h
vesicles, the wall of which is formed of a single stratu
ciliated homogeneous cells. These Planæads, or Blast
as they may be called, are formed in the very mixed so
of the Flagellatæ, especially the Volvoces (for inst
Synura). I noticed in September, 1869, on the Island Gi
on the coast of Norway, another very interesting form, w
I named *Magosphæra planula* (Figs. 172, 173). The
developed body of this forms a globular vesicle, the w
which is composed of from thirty to forty vibratory h
geneous cells, and which swims about freely in the sea.

FIG. 172.—The Norwegian Flimmer-ball (*Magosphæra planula*), s
ming by means of its vibratile fringes; seen from the surface.

FIG. 173.—The same, in section. The pear-shaped cells are seen b
together in the centre of the gelatinous sphere by a thread-like pro
Each cell contains both a kernel and a contractile vesicle.

reached maturity the society dissolves. Each sepa-
ll still lives a while independently, grows, and changes
crawling Amœba. This afterwards assumes a globu-
rm, and encases itself by exuding a structureless
ment. The cell now has just the appearance of a
on animal egg. After it has remained for a time in
uiescent state, the cell breaks up, by means of con-
division, first into 2, then into 4, 8, 16, 32 cells.
again arrange themselves so as to form a globular
, put forth cilia, and bursting the encasing integu-
swim about in the same Magosphæra-form from
we started. This accomplishes the entire life-history
remarkable Primitive Animal.[141]

we compare these permanent blastula-forms with the
swimming Flimmer-larvæ or planula-condition, of
r structure, of many other lower animals, we may
certainty infer therefrom the former existence of a
eval and long-extinct parent-form, the structure of
was essentially like that of the planula or blastula.
ill call this the Planæa, or Blastæa. The whole body,
fully developed condition, consisted of a simple hollow
filled with fluid or structureless jelly, the wall of
formed a single stratum of homogeneous cells,
d with cilia. Many different kinds and species of
a-like Primitive Animals must certainly have existed
rmed a distinct class of Protozoa, which we may call
ner-swimmers (*Planœada*). A remarkable proof of the
al philosophical genius with which Karl Ernst Baer
rated into the deepest secrets of the history of animal
tion, is that, as early as the year 1828 (ten years before
ll-theory was established), he guessed the significance

of the blastosphæra, and, truly prophetically, insi
it in his classical "Entwickelungsgeschichte der
(vol. i. p. 223). The passage in question says: "T
back we go in evolution, the more do we find
spondence in very different animals. This leads
question: Are not all animals in the beginning
evolution essentially alike, and is there not a prin
common to all? As the germ is the undevelop
itself, it is not without reason that it is asserted
simple vesicular form is the common primitive
which all animals, not only ideally, but also hi
develop." This latter sentence has not only on
but also phylogenetic significance, and is all the n
worthy because the blastula of the most diverse
and the constitution of its wall of a single cell-str
not then known. And yet Baer, in spite of th
deficiency of his empiric grounds, ventured the b
ment: "At their first appearance all animals ar
alike, and are merely hollow globes."

Next to the primæval ancestral form of the
the fifth stage in the human pedigree, is the Gastr
which arises from the Planæa. Of all ancestral
as we have already shown, is of pre-eminent ph
significance. Its former existence is certainly pro
very important gastrula, which is met with as a
germ-stage in the ontogeny of the most variou
(Fig. 171, *I*, *K*). We found that the gastrula, in i
palingenetic form, is a globular, oval or oblong-r
with one axis which has a simple cavity with o
(at one pole of the axis). This is the primitive
cavity with its mouth-opening. The intestinal w

of two cell-strata, which are, in fact, the two primary germ-layers, the animal skin-layer, and the vegetative intestinal layer.

The ontogenetic origin of the gastrula from the blastula at the present day affords us trustworthy intelligence as to the phylogenetic origin of the Gastræa from the Planæa. We found that on one side of the globular germ-membrane vesicle a groove-like depression begins, and this inversion (*invaginatio*) becomes continually deeper (Fig. 171, *H*). At last it is so great, that the outer, inverted part of the germ-membrane, or blastoderm, attaches itself closely to the inner, uninverted portion (Fig. 171, *I*). Now, if guided by this ontogenetic process, we wish to conceive the phylogenetic origin of the Gastræa in accordance with the fundamental law of Biogeny, we must imagine that the one-layered cell-society of the globular Planæa began, especially at one point of its surface, to absorb nourishment. At the nutritive point on the surface of the ball a groove-like depression was gradually formed by natural selection. The groove, which was at first quite shallow, in course of time became continually deeper. The function of nourishing, of absorption of nutriment, and digestion, was soon limited to the cells which lined the groove, while the other cells undertook the function of movement and covering. Thus originated the first division of labour among the originally homogeneous cells of the Planæa.

The first result of this earliest histological differentiation was the distinction of two different kinds of cells; within the hollow the nutritive cells, without, on the surface, the motive or locomotive cells. The distinction of the two primary germ-layers was thus caused. The inner cells

of the hollow formed the inner or vegetative layer, accomplishing the functions of nutrition; the outer cells of the covering formed the outer or animal layer, exercising the functions of locomotion and covering the body. This first and oldest process of differentiation is of such fundamental significance that it deserves the deepest thought. When we consider that the body of the human being with all its different parts, and also the body of all other higher animals, originates from these two simple primary germ-layers, we cannot over-estimate the phylogenetic significance of the gastrula. For in the quite simple primitive intestine, or the primitive intestinal cavity of the gastrula and its simple mouth-opening, the first real organ of the animal body, in a morphological sense, is gained; the earliest genuine organ, from which all the other organs have differentiated at a later period. The whole body of the gastrula is really only a "primitive intestine."

We have already pointed out the remarkable agreement between the palingenetic gastrula-forms of animals of the most diverse classes; of Sponges (Fig. 174, *A*), Polyps, Corals (Fig. 171, *I*), Medusæ, Worms (Fig. 175, *B*) Star-animals (*Echinoderma*, *C*), Articulated Animals (*Arthropoda*, *D*), Soft-bodied Animals (*Mollusca*, *E*), and Vertebrates (*F*). All these various forms of the palingenetic gastrula are much alike, and are only distinguished by such unessential and subordinate peculiarities, that the systematic zoologist, in his "natural system," could only represent them as different species of a single genus. The various kenogenetic gastrula-forms which have been described were also referable to that original palingenetic form (vol. i. p. 231). The gastrula proved to be a germ-form common to all classes of

animals, with the exception of the Protozoa. This highly important fact justifies the inference in accordance with the fundamental law of Biogeny, that the various ancestral

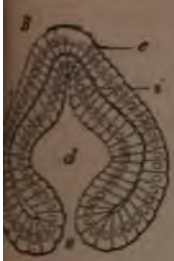


FIG. 175.

FIG. 176.

FIG. 177.

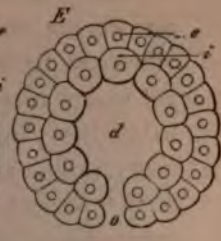


FIG. 178.

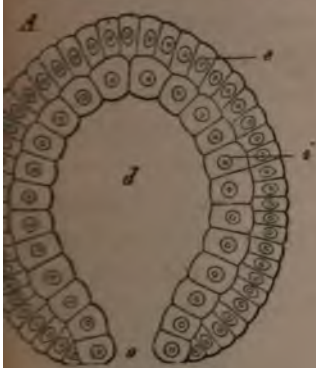


FIG. 174.

FIG. 179

FIG. 174.—(*A*) Gastrula of a Zoophyte (*Gastrophysema*), Haeckel.

FIG. 175.—(*B*) Gastrula of a Worm (Arrow-worm, *Sagitta*). After Kowalevsky.

FIG. 176.—(*C*) Gastrula of an Echinoderm (Star-fish, *Uraster*). After Alexander Agassiz.

FIG. 177.—(*D*) Gastrula of an Arthropod (Primitive Crab, *Nauplius*).

FIG. 178.—(*E*) Gastrula of a Mollusc (Pond-snail, *Limnæus*). After Karl Rabl.

FIG. 179.—(*F*) Gastrula of a Vertebrate (Lancelet, *Amphioxus*) After Kowalevsky.

lines of all these classes of animals have developed phylogenetically from the same parent-form. This most significant primæval parent-form is the Gastræa.

The Gastrea was at any rate already present in the sea during the Laurentian period, and by means of its vibratory fringe hurried about in the water, just like the yet extant free-moving ciliated gastrulæ of this age. Probably the primæval Gastræa, which has been extinct for many millions of years, differed from the living gastrula of the present day only in some unessential point. On grounds derived from Comparative Anatomy and Ontogeny, the explanation of which would lead us too far, we may assume that the Gastræa had already acquired sexual reproduction, and did not only propagate its species asexually (by division—bud-formation or spore-formation), as was probably the case with the four preceding ancestral stages. Presumably, single cells of the primary germ-layers assumed the character of egg-cells, others that of fertilizing seed-cells. (Cf. Chapter XXV.) This hypothesis is founded on the fact that sexual reproduction is yet met with in the same simple forms in the lowest Plant-Animals (*Zoophyta*), especially in the Sponges.

Two small animal forms are especially interesting in their bearing on this aspect of the Gastræa theory. They have as yet been little observed, but of all extant animals they are most nearly allied to the primæval Gastræa, and may therefore be called "the Gastræads of the present day."[142] One of these animals, *Haliphysema* (Figs. 180 and 181), has been described by Bowerbank as a Sponge; the other, *Gastrophysema*, by Carter as a Rhizopod (as "Squamulina"). The entire mature body of the developed person

of *Haliphysema* forms a most simple, cylindrical or egg-shaped pouch, the wall of which consists of two cell-strata. The cavity of the pouch is the stomach-cavity, and the

FIGS. 180, 181.—*Haliphysema primordiale*, an extant Gastræa-form. Fig. 180. External view of the whole spindle-shaped animal (attached by its foot to seaweed). Fig. 181. Longitudinal section of the same. The primitive intestine (*d*) opens at its upper end in the primitive mouth (*m*). Between the whip-cells (*g*) lie amœboid eggs (*e*). The skin-layer (*h*) below is encrusted with grains of sand, above with sponge-spicules.

opening at the top is the mouth-opening (Fig. 181, *m*). The two cell-strata forming the wall of the pouch are the

two primary germ-layers. These most simple Plant-Ani
differ from the gastrula principally in the fact that
former are attached by one end (that opposite to the mo
opening) to the bottom of the sea, while the latter
free. Moreover, the cells of the skin-layer are coalescent
have included many foreign bodies, such as sponge-spic
sand-grains, etc., which serve to support the body-
(Fig. 180). The intestinal layer, on the other hand,
sists merely of a stratum of ciliated cells (Fig 181
When the *Haliphysema* is sexually mature, individual
of its entoderm assume the character of female egg-c
on the other hand, individual cells of its exoderm bec
male seed-cells; the fertilization of the former by the l

FIGS. 182, 183.—Ascula of a Sponge (*Olynthus*). Fig. 182, from th
side; Fig. 183, in longitudinal section: *g*, primitive intestine; *o*, pri
mouth; *i*, intestinal layer; *e*, skin-layer.

takes place directly through the stomach-cavity. A true palingenetic gastrula (Fig. 174) develops, just as in the Monoxenia (Fig. 171), from the fertilized egg. This swims about for a time in the sea, then attaches itself, and in this state resembles a simple young-form, which occurs in the course of the evolution of many other Plant-Animals, and which is called the ascula (Figs. 182, 183). In consequence of the absorption of foreign bodies by the exoderm, it becomes the *Haliphysema*.

When we consider that there is no other important difference between the free-swimming gastrula and this attached, simplest Plant-animal, we are fairly justified in stating that in the simplest form of Gastræa sexual reproduction must have taken place in the same way. In the Gastræads, just as in Plant-animals, both kinds of sexual cells—egg-cells and sperm-cells—must have formed in the same person; the oldest Gastræads must, therefore, have been hermaphrodite. For Comparative Anatomy shows that hermaphroditism, that is, the union of both kinds of sexual cells in one individual, is the oldest and original condition of sexual differentiation; the separation of the sexes (*Gonochorismus*) did not originate till a later period.

TABLE XVII.

Systematic Survey of the five earliest evolutionary stages of the Human Ancestral Line, compared with the five earliest stages of Individual and of Systematic Evolution.

Form-Value Of the five earliest stages of the animal body.	**Phylogeny.** The five earliest stages in the evolution of the tribe.	**Ontogeny.** The five earliest stages in the evolution of the germ.	**The System.** The five earliest stages in the animal system.
1. *First Stage.* A quite simple cytod (a non-nucleated plastid).	1. **Monera.** The oldest animal Monera (originating by spontaneous generation).	1. **Monerula.** A non-nucleated animal-egg (after fertilization and after loss of the germ-vesicle).	1. **Monera.** Protamœba, Bathybius, and other extant Monera.
2. *Second Stage.* A simple cell (a nucleated plastid).	2. **Amœba.** Oldest animal Amœba.	2. **Cytula.** A nucleated, fertilized animal-egg ("first cleavage globule").	2. **Amœba.** Extant Amœba.
3. *Third Stage.* A quite simple aggregation of simple, similar cells.	3. **Synamœba.** The oldest aggregation of animal Amœbæ.	3. **Morula.** "*Mulberry-germ.*" A globular mass of cleavage-cells.	3. **Labyrinthula.** A mass of similar, one-celled primitive animals.
4. *Fourth Stage.* A simple hollow globe, filled with liquid, the wall of which consists of a single stratum of homogeneous cells.	4. **Planæa.** An animal hollow globe, the wall of which consists of a single stratum of ciliated cells. (*blastæa.*)	4. **Blastula.** A hollow globe, the wall of which consists of a single stratum of homogeneous cells (the Planula of lower animals). (*blastosphæra.*)	4. **Magosphæra.** A hollow globe, the wall of which consists of a single stratum of homogeneous ciliated cells.
5. *Fifth Stage.* A hollow body, with a single axis, the wall of which consists of different cell-strata; with an opening at one pole of the axis.	5. **Gastræa.** Parent-form of intestinal animals, or *Metazoa.* Simple primitive intestine with primitive mouth. The body-wall is formed by the exoderm and the entoderm.	5. **Gastrula.** Intestinal larva. A simple intestinal cavity with a mouth-opening. The body-wall is formed by the two primary germ-layers.	5. **Haliphysema.** A quite simple plant-animal. An unarticulated uniaxial person, the body-wall of which consists of the exoderm and the entoderm.

CHAPTER XVII.

THE ANCESTRAL SERIES OF MAN.

II.—From the Primitive Worm to the Skulled Animal.

The Four Higher Animal Tribes are descended from the Worm Tribe.—The Descendants of the Gastræa; in one direction the Parent Form of Plant-Animals (Sponges and Sea-Nettles), in the other the Parent Form of Worms.—Radiate form of the former, Bilateral form of the latter.—The Two Main Divisions of the Worms, Acœlomi and Cœlomati: the former without, the latter with, a Body Cavity and Blood-vessel System.—Sixth Ancestral Stage: Archelminthes, most nearly allied to Turbellaria.—Descent of the Cœlomati from the Acœlomi.—Mantled Animals (*Tunicata*) and Chorda-Animals (*Chordonia*).—Seventh Stage: Soft-Worms (*Scolecida*).—A Side Branch of the latter: the Acorn-Worm (*Balanoglossus*).—Differentiation of the Intestinal Tube into Gill-intestine and Stomach-intestine.—Eighth Stage: Chorda-Animals (*Chordonia*).—Ascidian Larva exhibits the Outline of a Chorda-Animal.—Construction of the Notochord.—Mantled Animals and Vertebrates as Diverging Branches of Chorda-Animals.—Separation of Vertebrates from the other Higher Animal Tribes (Articulated Animals, Star-Animals, Soft-bodied Animals).—Significance of the Metameric Formation.—Skull-less Animals (*Acrania*) and Skulled Animals (*Craniota*).—Ninth Ancestral Stage: Skull-less Animals.—Amphioxus and Primitive Vertebrate.—Development of Skulled Animals (Construction of the Head, Skull, and Brain).—Tenth Ancestral Stage: Skulled Animals, allied to the Cyclostomi (*Myxinoidæ* and *Petromyzonidæ*).

"Not like the gods am I! Full well I know;
But like the worm which in the dust must go,
And, finding in the dust his life and weal,
Is crushed and buried by the traveller's heel.—

> Why dost thou grin at me, thou hollow skull?
> As though of old thy brain, like mine, was vexed,
> Had looked to find bright day, but in the twilight dull,
> In search for truth, was sad and sore perplexed!"
>
> GOETHE.

BOTH in prose and in poetry man is very often compared to a worm. "A miserable worm," "a poor worm," are common and almost compassionate phrases. If we cannot detect any deep phylogenetic reference in this zoological metaphor, we might at least safely assert that it contains an unconscious comparison with a low condition of animal development which is interesting in its bearing on the pedigree of the human race. For there is no doubt that the vertebrate tribe, in common with those of the other higher classes of animals, have developed phylogenetically from that multiform group of lower invertebrate animals which are now called Worms. However closely we limit the zoological significance of the word "Worm," it yet remains indubitable that a large number of extinct Worms must be reckoned among the direct ancestors of the human race.

The group of Worms (*Vermes*) is much more limited in the Zoology of the present day, than was the same class in the older Zoology, which followed the system of Linnæus. It, however, yet includes a great number of very diverse lower animals, which, phylogenetically, we may regard as the few last living twigs of an immense spreading tree, the trunk and main branches of which have for the most part long since died off. On the one side, among the widely divergent classes of Worms, are found the parent-forms of the four higher tribes of animals, the Molluscs, Star-animals, Articulates, and Vertebrates; on the other side,

ral comprehensive groups and also single isolated genera Worms are to be regarded as root-suckers which have outed directly from the rest of the primæval family-tree the Worms. Some of these suckers have evidently nged but little from the long-extinct parent-form, the mitive Worm (*Prothelmis*), which is immediately con-ted with the Gastræa.

Comparative Anatomy and Ontogeny clearly and sig-icantly prove that the Gastræa must be regarded as direct ancestor of this Primitive Worm. Even now, a trula develops from the egg of all Worms after its avage. The lowest and most imperfect Worms retain oughout life an organization so simple that they are but le raised above the lowest Plant-animals, which are also mediate descendants of the Gastræa, and which also yet elop directly from the gastrula. If the genealogical ation of these two lower animal tribes, the Worms and Plant-animals, is closely examined, it becomes evident t the most probable hypothesis of their descent is, that two originated, as independent branches, directly from Gastræa. On the one side, the common parent-form of Worms developed from the Gastræa; as, on the other e, did the common parent-form of the Plant-animals. Tables XVIII. and XIX.)

The tribe of Plant-animals (*Zoophytes*, or *Cœlenterata*) w comprehends, on the one side, the main class of Sponges *ongiæ*); on the other, the main class of the Sea-nettles *calephæ*); to the former belong the Gastræads and riferæ, to the latter the Hydroid-polyps, the Medusæ, enophoræ, and Corals. From the Comparative Anatomy l the Ontogeny of these we may infer, with great pro-

bability, that all these Plant-animals descend from a common and very simple parent-form, the structure of which resembled that of the ascula in essential points (Figs. 182, 183, p. 68). The uniaxial outline of the ascula and the gastrula is usually retained by the Sponges, while in most Sea-nettles (*Acalephæ*) transverse axes have been differentiated in the course of further evolution, thus giving rise to a characteristic radiate structure with a pyramidal general outline.

In distinction from this predominant radiate outline of Plant-animals, a marked bilateral general outline is developed from the first in the second offshoot from the gastrula, in the Worms. As the radiate form is marked by adaptation to an adherent mode of life, so is the bilateral form by adaptation to certain definite acts of free locomotion. The constant direction and carriage of the body which would be maintained in this mode of free locomotion, conditioned the two-sided, or bilateral outline of the symmetrical Worms. Even the parent-form of the latter, the Primitive Worm (*Prothelmis*) must have acquired this character, and thus have become distinguished from the uniaxial parent-form of the Plant-animals. In this simple mechanical impetus, in the defined free locomotion of the Worms, on the one hand, and in the stationary mode of life of the earliest Plant-animals on the other, we must look for the efficient cause which produced in the one the bilateral or two-sided, in the other the radiate outline of the body. The former, the bilateral outline, has been inherited by the human race from the Worms.

Except through the Gastræa, the common parent-form of Plant-animals and Worms, the human race is, therefore,

ot related to the Plant-animals. It will be our next task o consider more closely the pedigree of Man in so far as t coincides with that of the Worms. Let us examine how far the Comparative Anatomy and Ontogeny of Worms justify us in looking among the latter for primæval ancestors of Vertebrates, and therefore of Man. For this end we must first consider the zoological system of Worms. In accordance with the most recent investigations of the Comparative Anatomy and Ontogeny of Worms, we divide (without reference to the many and various peculiarities of the numerous separate classes, which in this place do not interest us) the whole mass of forms within this tribe into two large main groups. The first main group, which we call Bloodless Worms (*Acœlomi*), comprehends the earlier division of the lower Worms, which have no true body-cavity, no system of blood-vessels, no heart, no blood, —in short, none of the parts connected with this organ-system. The second main group, on the contrary, called Blood-worms (*Cœlomati*), are distinguished from the former by the possession of a true body-cavity, and also by the presence of a blood-like fluid, which fills this cavity; most of them also develop special blood-vessels, which again cause further correlated advances in structure. The relation of these two main groups of Worms is very evidently phylogenetic. The Acœlomi, which are very nearly allied to the Gastræa and the Plant-animals, are to be regarded as an earlier and lower group, from which the more recent and higher division of the Cœlomati developed, perhaps towards the end of the Laurentian Period.

We will first carefully examine the lower group of Worms, the Acœlomi, among which we must look for the

sixth ancestral stage of the human race, the stage im diately following the gastrula. The name "Acœlo signifies "Worms without a body-cavity, or cœloma," therefore without blood, or vascular system. The ext Acœlomi are generally included in a single class, which, account of their flattened bodies, are called Flat-wo (*Plathelminthes*). To this class belong the Gliding-wo (*Turbellaria*), which live independently in the water; the parasitic intestinal Sucking-worms (*Trematoda*), the Tape-worms (*Cestoda*), which have become yet m degraded by parasitism. The phylogenetic relations of three forms of Flat-worms are very evident; the Sucki worms originated from the free Gliding-worms by adaptat to a parasitic mode of life; and, by a yet more complet parasitic life, the Tape-worms originated from the Sucki worms. These are striking examples of the gradu increasing degeneration of the most important organs.

In addition to these well-known extant Flat-wor great numbers of other Acœlomi must have lived du the Archilithic Epoch, which in general form were much like those of the present day, but were, in s respects, yet more simply organized, and were, in t lowest stages of development, immediately connected w the Gastræads. The whole of these lowest Acœlomi, am which the common parent-form of the whole Worm t (the *Prothelmis*) must have been, may be classed as "Pri tive Worms" (*Archelminthes*).

The two classes of the Acœlomi, the Primitive Wo and the Flat-worms, represent in their external form simplest bilateral condition of the animal body. body is a simple oval, usually somewhat flattened, w

out any appendage (Figs. 184, 185). The dorsal side of the leaf-like body differs from the ventral side, on which the Worm creeps. Accordingly, even in these most simple Worms there are the three definite axes which mark the bilateral type-form, and which re-occur in the human body and in that of all higher animals: (1) a longitudinal axis (main axis), which passes from front to rear; (2) a lateral axis, passing from right to left; and (3) a sagittal axis, passing from the dorsal to the ventral surface. (Cf. vol. i. p. 257.) This so-called symmetrical or "bilateral" arrangement of the outline of the body is simply the mechanical result of adaptation to a creeping form of locomotion, during which one end of the body is always directed forwards. The geometric outline of the gastrula, as of the ascula, has but one axis with unequal poles (*Monaxonia diplopola*). The typical outline of Worms, as of Vertebrates, is, on the contrary, bilateral, with tranverse axes (*Stauraxonia dipleura*).[144]

The whole outer surface of the Gliding-worms (*Turbellaria*) is covered, as in the gastrula, with a thick, fine ciliated coat; that is, with a fur-like covering of extremely fine and close microscopic hairs, which are direct processes of the uppermost cells of the epidermis, and maintain an uninterrupted whirling or vibratory motion (Fig. 184, *f*). The constant vibrations of these cilia cause a continued current of water over the surface of the body. Fresh water is constantly conveyed to the surface of the skin by this current, thus permitting respiration in its simplest form (skin-respiration). A similar ciliated covering, just as is seen in the extant Gliding-worms of our fresh-water seas, presumably covered our extinct ancestors of the Primitive

Worm group, the *Archelminthes*. They inherited th ciliated dress directly from the Gastræa.

If we now make various vertical sections (longitudin and transverse) through the simple body of the Gliding-worm (and that of the *Archelminthes* which are certainly ve closely allied to the former), we soon discover that the internal structure is considerably higher than that of th Gastræads. We first observe that the two primary germ layers (inherited from the Gastræa) have differentiated in several cell-strata. The skin-layer and the intestinal layer have each split into two strata. The four secondary germ layers, which are thus produced, are the same that we found resulted from the first differentiation of the two primary germ-layers in the embryo of the Vertebrate also. (Cf. th transverse sections through the larval Amphioxus an Earth-worm, Figs. 50 and 51, p. 236, and Plate IV. Fig. 2 Plate V. Fig. 10.)

The highly important histological differentiation of the four secondary germ-layers led directly to further organol gical processes of differentiation, by which the organism o the Primitive Worms was soon considerably raised abov that of the Gastræads. In the latter there was really, i a morphological sense, but a single organ, the primitive inte tine, with its mouth-opening. The whole body was nothin but an intestinal canal; the intestinal wall was at th same time the wall of the body. Of the two cell-layer forming this intestinal wall, the inner accomplished th functions of nutrition, the outer those of motion an covering. As some of the cells of the primary germ-layer developed into egg-cells, and others into sperm-cells, the layers also performed the function of reproduction. In th

Primitive Worms, however, simultaneously with the formation of the secondary germ-layers, these various functions also began to be distributed to various organs, which detached themselves from the original main organ, the primitive intestine. Special organs originated for reproduction (sexual glands), for secretion (kidneys), for motion (muscles), and for sensation (nerves and sense-organs).

In order to obtain an approximate picture of the simplest form in which all these various organs first appeared in the Primitive Worms, it is only necessary to examine the most imperfect forms of Gliding-worms (*Turbellaria*), as they exist at the present time in salt and fresh water. They are mostly very small and insignificant Worms of the simplest form, many being scarcely a millimetre or a few millimetres in length. In the simplest species of Gliding-worms the greater part of the oval body is occupied by the intestinal canal. This is a very regularly shaped pouch with an opening, representing both mouth and anus (Fig. 184, *m*). At the anterior section of the intestinal tube, which is separated as a throat (*pharynx*, *sd*), the fibrous layer is very thick, a thick muscular layer. Immediately outside the intestinal-fibrous layer lies the skin-fibrous layer, which in most worms appears as a large skin-muscle sac. Above the throat in Gliding-worms a nerve system of the simplest form is already visible in front, a pair of small nerve-knots, or ganglia, which from their position are called the "upper throat ganglia," or "brain" (Fig. 185, *g*). Delicate nerve-threads (*n*) pass from this to the muscles and to the ciliated skin-sensory layer. A pair of quite simple eyes (*au*) and nose-pits (*na*) are to be found in a few Gliding-worms. The Flat-worms are also universally provided with

a pair of simple kidney-canals ("excretory organs"), the form of two long, thin, glandular tubes, which trave the right and left sides of the intestine and open at t hinder end of the body (Fig. 184, *nm*). We found that t

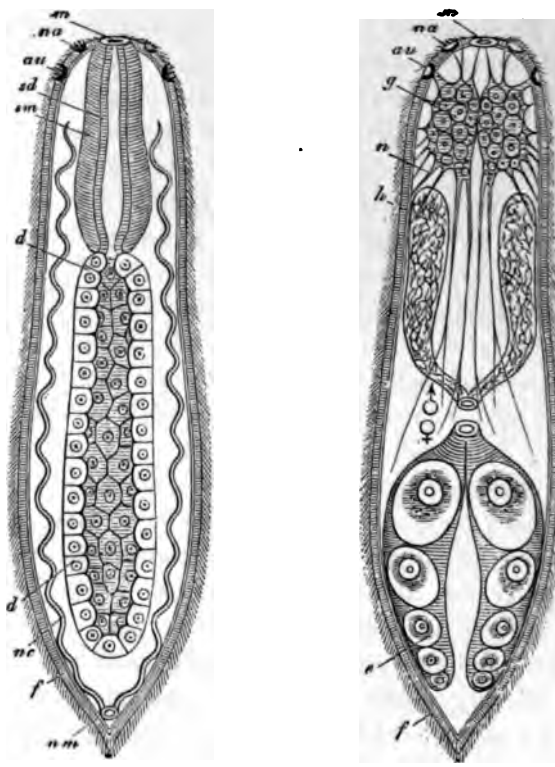


FIG. 184.—A simple Gliding-worm (*Rhabdocœlum*): *m*, mouth; *sd*, thr epithelium; *sm*, throat-muscles; *d*, stomach-intestine; *nc*, kidney du *nm*, opening of the kidneys; *au*, eye; *na*, nose-pit.

FIG. 185.—The same Gliding-worm, showing the remaining organs brain; *au*, eye; *na*, nose-pit; *n*, nerves; *h*, testes; ♂, male openi ♀, female opening; *e*, ovary; *f*, ciliated outer-skin.

nitive kidney canals in the vertebrate embryo
ared at a very early period, shortly after the first
ation of the middle germ-layer (*mesoderma*). The
ce of these at so early a period shows that the
are very important primordial organs. It also
eir universal existence in all Flat-worms; for even
-worms, which, in consequence of the adoption of a
mode of life, have lost the intestine, yet have the
eting primitive kidneys, or "excretory ducts." The
em, therefore, to be older and of greater physiologi-
rtance than the blood-vessel system, which is wholly
in the Flat-worms. The sexual organs appear
y of the Gliding-worms in a very complex form;
others their form is very simple. Most of them
maphrodites; that is, each individual worm has
ale and female sexual organs. In the simplest
ve find a testis in the anterior part (Fig. 185, *h*),
or double ovary behind (*a*). One of these simplest
Acœlomi, such as we find among the lowest Rhab-
may give us an approximate idea of the structure
Primitive Worm, which forms the sixth stage in
nan pedigree.

se ancestors of the human race, which, on account
r general organization, must be placed among the
ss Worms (*Acœlomi*), must have been represented
the Archilithic Epoch by a large number of various
forms. The lowest of these must have been directly
ted with the Gastræads (the fifth ancestral stage); the
ighly developed must, on the other hand, have been
connected with the Cœlomati (the seventh stage).
wever, our present knowledge of the Comparative

Anatomy and Ontogeny of the Acœlomi is very fragm tary, and much too imperfect to enable us to point wi certainty to the series of the various stages, we will n attempt a detailed arrangement of them. We will tu instead to the seventh stage in the human pedigree, whi belonged to the multiform group of the Blood-beari Worms (*Cœlomati*).

The great organic advance in structure by which t Blood-bearing Worms, or Cœlomati, developed from t older Bloodless Worms, or Acœlomi, consisted in the fo mation of a body-cavity (*cœloma*), and of a nutritive jui filling the latter, the first blood. All the lower anima with which we have yet occupied ourselves in our Ph logeny, all the Primitive Animals and Plant-animals, a like the Acœlomi, bloodless and without a body-cavity. the formation of a special vascular system, the earli Cœlomati made a very great advance. Much of the co plexity in the organic structure in the four higher tribes animals is based on the differentiation of the vascul system, which they have inherited from the Blood-beari Worms.

The first development of a true body-cavity (*cœlom* is referable to the separation of the two fibrous layers; the formation of a spacious cavity between the outer sk fibrous layer and the inner intestinal-fibrous layer. In t fissure-like gaps, which formed between the two germ-laye a juice collected, which penetrated through the intesti wall. This juice was the first blood, and the gaps betwe the two germ-layers formed the first rudiment of the bod cavity. The union of these gaps formed the simple cœlo the large cavity, containing blood or lymph, which plays

important a part in all the higher animals as the receptacle of the very extensive intestines. The formation of this cœlom, and of the blood-vessels developed in connection with it, exercised a very great influence on the further evolution of the animal organization. The most important result was, that it allowed the conveyance of rich nutritive juices to those parts of the body lying near the circumference, and developing at a considerable distance from the intestinal canal. The intimate correlation, or reciprocity of the parts, necessarily occasioned, in direct connection with the progressive development of the blood-vessel system, many other important advances in the structure of the body of the Blood-bearing Worms.

Just as among the Acœlomi, so also among the Cœlomati, the pedigree of our race must have passed through a large number of diverse ancestral stages. But among extant Cœlomati (which form but a very small fraction of this once multiform group), there are but very few Worms which can with certainty be regarded as nearly allied to the long-extinct ancestors of Man. In this respect, but a single class of Cœlomati is really of prominent importance; these are the Mantled Animals (*Tunicata*), to which belong the Ascidia already known to us. Our careful examination of the structure and germ-history of the Ascidian and the Amphioxus have shown the extreme importance of these very interesting animal forms. (Cf. Chapters XIII. and XIV.) That examination fully justifies us in asserting that among the ancestors of the Vertebrates (and therefore of Man) there was an unknown extinct cœlomate species, to which the nearest allied form among extant animals is the Appendicularia (Fig. 187), of which we have already

spoken, and the tailed Ascidian larva. We will for t present call this kind of Worm, which was primarily d tinguished by the possession of a notochord, the Chor animal (*Chordonium*). The Ascidians on the one hand, a the Vertebrates on the other, developed, as two diverg branches, from these Chorda-animals. The common pare form of the Chorda-animals themselves was a cœlomate fo which finally must have descended from the Acœlomi, a from the Archelminthes.

Many connecting intermediate forms must, of course, h existed between these two groups of Worms, between t Primitive Worms and the Chorda-animals. Unfortunat however, zoological knowledge is at present especially i perfect with regard to these important intermediate fo of the multiform Worm tribe. For very evident reas none of these Worms could leave fossil remains. For, l the great majority of other Worms, they had no hard p in their bodies. Most even of the known fossil Wo are worthless, for they tell us little or nothing of the most portant structural features of the soft body. Fortunat however, we can in great measure satisfactorily fill the c siderable palæontological gap in this part of our pedig with the help of the Comparative Anatomy and Ontogen Worms. If, on the one hand, we examine the structure mode of development of the lower Worms from the Glidi Worms (*Turbellaria*), and, on the other hand, the Anat and Ontogeny of the Ascidians, it is not difficult, step step, to re-construct in imagination the connecting in mediate forms, and to insert a series of extinct ances forms between the Acœlomi and the Chordonia. T series of forms under the name of Soft-worms (*Scoleci*

we will consider as the seventh stage in the human pedigree.

An examination of the Comparative Anatomy of the various Scolecid forms, which we might perhaps distinguish here, would lead us much too far into the difficult details of the Comparative Anatomy and Ontogeny of the Worms. For our purpose it seems more important to call attention to those phylogenetic advances, by means of which the organization of the earliest Blood-bearing Worms was in the end elevated to that of the Chorda-animals. The Comparative Anatomy and Ontogeny of the Gliding-worms and of the Ascidians justify us in giving special weight to the significant differentiation of the intestinal canal into two distinct divisions; into an anterior division (the gill-intestine), which accomplishes respiration, and a posterior division (the stomach-intestine), which accomplishes digestion. As in Gastræads and Primitive Worms, so also in the Ascidian larva, the intestinal canal is at first a simple pouch-like body, provided merely with a mouth-opening. A second opening, the anus, does not develop till a later period. Gill-openings afterwards appear in the anterior section of the intestinal canal, by which the whole anterior intestine is transformed into a gill-body. This remarkable arrangement is, as we found, quite peculiar to Vertebrates, and, except in the Ascidians, occurs nowhere else. Among extant Worms there is, however, a single isolated and very remarkable Worm form, which in this respect may be regarded as distantly allied to the Ascidia and to Vertebrates, and perhaps as an off-shoot from the Soft-worms (*Scolecida*). This is the so-called "Acorn-worm" (*Balanoglossus*, Fig. 186), which lives in the sand of the sea-shore. The in-

teresting points connecting this with Ascidians and Skull-less Animals (*Acra* were first accurately obse and explained by Gegenbaur. though this singular Balanoglo is in many other respects pec in its organization, so that Ge baur rightly ranked it as the presentative of a special (*Enteropneusta*), yet the struc of the anterior section of the testinal tube is exactly simila that of Ascidians and Skull Animals (*k*), a gill body, the of which are pierced on either by gill-openings and are suppo by gill-arches. Now, although Acorn-worm in other points o structure may differ very siderably from those extinct worms (*Scolecidæ*), which we regard as direct ancestors of race, and as intermediate between the Primitive W

FIG. 186.—A young Acorn-worm *anoglossus*). (After Alexander Ag *r*, acorn-like proboscis; *h*, collar; openings and gill-arches of the anteri testine, in a long row one behind a on each side; *d*, digestive posterior tine, filling the greater part of the cavity; *v*, intestinal vessel, lying be two parallel folds of skin; *a*, anus.

and the Chorda-animals, yet, in virtue of this characteristic structure of the gill-intestine, it may be considered a remotely allied collateral line of the Soft-worms. The development of an anus (Fig. 186, *a*) at the end opposite to the mouth, is also a considerable advance in the structure of the intestine. The further development of the blood-vessel system in the Acorn-worm also indicates a marked advance. In the ciliary surface of the skin, on the contrary, it recalls the Gliding-worms. The sexes are separated, while our scolecid ancestors were probably hermaphrodite.[145]

From a branch of the Soft-worms, the group of Chorda-animals (*Chordonia*), the common parent-group of the Mantle-animals and Vertebrates also developed. The process which primarily led to the development of this important group of the cœlomati, was the formation of the inner axial skeleton (the notochord, or *chorda dorsalis*), which at the present day we find permanently retained in its simplest form in the lowest Vertebrate, the Amphioxus. We saw that this notochord is already found in the tailed and free-swimming larva of the Ascidian (Plate X. Fig. 5). The chorda does, indeed, serve specially as a support for the rudder-like tail of the larval Ascidian, but its anterior extremity passes in between the intestinal and medullary tubes within the actual body of the larva. A transverse section of this larva therefore shows that arrangement of the most important organs which is characteristic of the vertebrate type: in the centre is the firm notochord, which supports the other organs and serves especially as a base and point of attachment for the motive trunk muscles; above this notochord, on the dorsal side, is the central

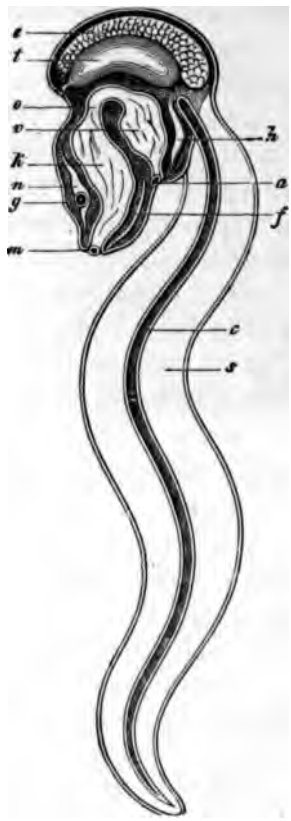
nervous system in the form of a medullary tube; below, on the ventral side, is the intestinal tube, the anterior half of which is a respiratory gill-intestine, its posterior half a digestive stomach-intestine. It is true that the free-swimming larva of the extant Ascidian possesses this typical vertebrate character only for a short time; it soon relinquishes its free roving mode of life, puts off its oar-like tail with the notochord, adheres to the bottom of the sea, and then undergoes that very great retrogression, the surprising final result of which we have already observed (Chapters XIII. and XIV.). Nevertheless, the Ascidian larva, in its very transitory evolution (for a brief space), affords us a picture of the long extinct Chordona-form, which must be regarded as the common parent-form of Mantle-animals and Vertebrates. There is even yet extant a small and insignificant form of Mantle-animal which throughout life retains the structure of the Ascidian larva with its oar-like tail and its free-swimming mode of life, and which reproduces itself in this form. This is the remarkable Appendicularia (Fig. 187), which we have already examined.

If we ask ourselves what conditions of adaptation could possibly have had so remarkable a result as the development of the notochord, and the modification of a branch of the Soft-worms into the parent-form of the Chorda-animals, we may with great probability answer, that this result was effected by the habituation of the creeping Soft-worm to a swimming mode of life. By energetic and continued swimming movements, the muscles of the trunk would be greatly developed, and a strong internal point of attachment would be very favourable to this muscular

activity. A support of this kind might arise by enlargement and concrescence of the germ-layers along the longitudinal axis of the body; and the differentiation of an independent bony cord from this axial cord gave rise to the notochord. (Cf. Fig. 88, 89, vol. i. pp. 300, 301.) In correlation to the formation of this central notochord, the simple nerve-ganglia, lying over the throat in the Soft-worms, lengthened into a long nerve-cord, reaching from front to rear, above the notochord; in this way, the medullary tube originated from the "upper throat ganglia."

As we have already minutely considered the great significance of the Ascidians (Fig. 188) in this respect, as well as their close relations to the Amphioxus (Fig. 189), we will not tarry longer over this point now. I will repeat, that we must by no means regard the Ascidian as the direct parent-form of the Amphioxus and of the other Vertebrates. On the contrary, we assert that, on the one hand the Ascidians, and on the other the Vertebrates, have both descended from one unknown Worm form, which has long been extinct; the nearest relatives of this among existing animals are the Ascidian larvæ and the Appendicularia (Fig. 187). This unknown common parent-form must have belonged to the group of Chorda-animals, which we pointed out as the eighth ancestral stage in the human pedigree.[146] Although we cannot form an entirely satisfactory idea as to all points of external and internal structure of this Chorda-animal, there is no doubt that, like its near relatives, the Mantle-animals, and like the preceding ancestral stage represented by the Soft-worms and Primitive Worms, it must be classified in the natural system of the animal

kingdom as a genuine Worm. The difference between and other genuine Worms cannot have been greater than



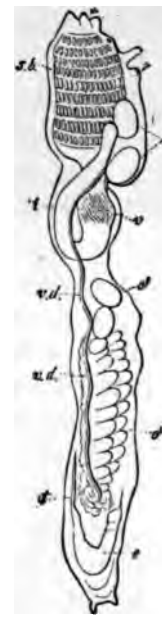


FIG. 187.—Appendicularia, seen from the left side: *m*, mouth; *k*, g intestine; *o*, œsophagus; *v*, stomach; *a*, anus; *n*, nerve-ganglia (up throat-knots); *g*, ear-vesicle; *f*, ciliated groove under the gill; *h*, hea *t*, testes; *e*, ovary; *c*, notochord; *s*, tail.

FIG. 188.—Structure of an Ascidian (seen from the left, as in Fig. and Fig. 14, Plate XI.): *sb*, gill-sac; *v*, stomach; *i*, large intestine; heart; *t*, testes; *vd*, seed-duct; *o*, ovary; *o'*, matured eggs in the bo cavity. (After Milne Edwards.)

the difference between the extant Tape-worms and Ringed Worms (*Annelida*). Moreover, in a certain sense we may regard the extant Appendicularia as a last remnant of the Chordonia class.

We have now studied the most important animal forms which occur in the pedigree of the human race, and which, in the zoological system, must be classed among the Worms. In leaving this lower class, and tracing our ancestry henceforth exclusively within the vertebrate tribe, we at once leave behind the great majority of animal forms, which branched off from the worm tribe in entirely different directions. When, in a previous chapter (IX.), the vertebrate nature of man was proved, it was incidentally mentioned that the very great majority of animals are in no way directly allied to our tribe. The parent-forms of the three other higher Animal tribes, the Articulated Animals (*Arthropoda*), Star-animals (*Echinoderma*), and Soft-bodied Animals (*Mollusca*), like the vertebrate tribe, originated from the

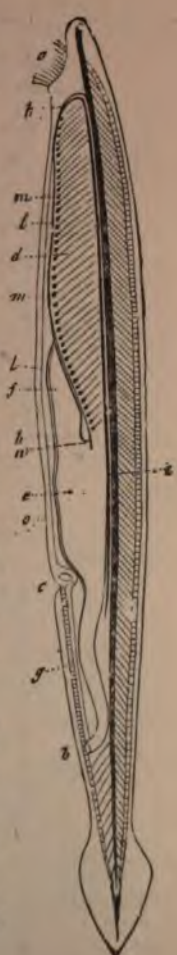


FIG. 189.—Lancelet (*Amphioxus lanceolatus*), twice the actual size, seen from the left (the longitudinal axis is represented vertically, the mouth turned upward, the tail downward, as in Plate XI. Fig. 15): *a*, mouth-opening, surrounded by cilia; *b*, anal opening; *c*, ventral opening (*Porus abdominalis*); *d*, gill-body; *e*, stomach; *f*, liver-cœcum; *g*, large intestine; *h*, cœlom: *i*, notochord (under it the aorta); *k*, arches of the aorta; *l*, main gill-artery; *m*, swellings on its branches; *n*, hollow vein; *o*, intestinal vein.

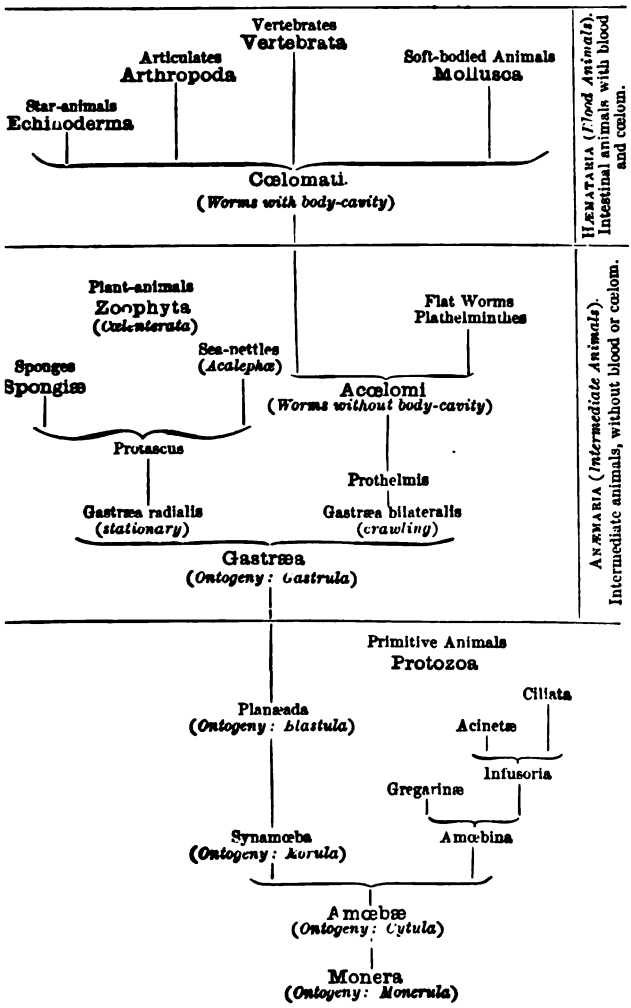
TABLE XVIII.

Systematic Survey of the Phylogenetic System of the Animal Kingdom founded on the Gastræa Theory and the Homology of the Germ-layers.

Tribes or Phyla of the Animal Kingdom.	*Main Classes or Branches of the Animal Kingdom.*	*Classes of the Animal Kingdom.*	*Systematic Name of the Classes.*
	FIRST SUB-KINGDOM: PRIMITIVE ANIMALS (*Protozoa*). Animals without germ-layers, intestine, or true tissues.		
A. Primitive Animals **Protozoa**	I. Egg-animals *Ovularia*	1. Monera	1. Monera
		2. Amœbæ	2. Lobosa
		3. Gregarines	3. Gregarines
	II. Infusorial animals *Infusoria*	4. Sucking Infusoria	4. Acinetæ
		5. Ciliated Infusoria	5. Ciliata
	SECOND SUB-KINGDOM: INTESTINAL ANIMALS (*Metazoa*). Animals with two primary germ-layers, intestines and tissues.		
B. Plant-Animals **Zoophytes**	III. Sponges *Spongiæ*	6. Primitive intestinal animals	6. Gastræada
		7. Sponges	7. Porifera
	IV. Sea-nettles *Acalephæ*	8. Corals	8. Coralia
		9 Hood-jellies	9. Hydromedusæ
		10. Comb-jellies	10. Ctenophora
C. Worms **Vermes**	V. Bloodless worms *Acœloma*	11. Primitive worms	11. Archelminthes
		12. Flat-worms	12. Plathelminthes
	VI. Blood-worms *Cœlomati*	13. Round-worms	13. Nemathelminthes
		14. Arrow-worms	14. Chætognatid
		15. Wheel-animalcules	15. Rotatoria
		16. Moss-polyps	16. Bryozoa
		17. Mantle-animals	17. Tunicata
		18. Acorn-worms	18. Enteropneusta
		19. Star-worms	19. Gephyrea
		20. Ringed-worms	20. Annelida
D. Soft-bodied Animals **Mollusca**	VII. Headless shell-fish *Acephala*	21. Lamp-shells	21. Spirobranchia
		22. Mussels	22. Lamellibranchia
	VIII. Head-bearing shell-fish *Eucephala*	23. Snails	23. Cochlides
		24. Cuttles	24. Cephalopoda
E. Star-Animals **Echinoderma**	IX. Ringed-arms *Cœlobrachia*	25. Sea-stars	25. Asterida
		26. Sea-lilies	26. Crinoida
	X. Armless *Lipobrachia*	27. Sea-urchins	27. Echinida
		28. Sea-cucumbers	28. Holothuria
F. Articulated Animals **Arthropoda**	XI. Gill-breathers *Carides*	29. Crabs	29. Crustacea
	XII. Tube-breathers *Tracheata*	30. Spiders	30. Arachnida
		31. Centipedes	31. Myriopoda
		32. Flies	32. Insecta
G. Vertebrate Animals **Vertebrata**	XIII. Skull-less *Acrania*	33. Tube-hearts (Lancelets)	33. Leptocardia
	XIV. Single-nostrilled *Monorrhina*	34. Round-mouths (Lampreys)	34. Cyclostoma
	XV. Amnion-less *Anamnia*	35. Fishes	35. Pisces
		36. Mud-fish	36. Dipneusta
		37. Amphibians	37. Amphibia
	XVI. Amnion-animals *Amniota*	38. Reptiles	38. Reptilia
		39. Birds	39. Aves
		40. Mammals	40. Mammalia

TABLE XIX.

letic Pedigree of the Animal Kingdom, founded on the Gastræa Theory and the Homology of the Germ-layers.[24]



worm tribe; but the parent-forms of the three for
belong to worm-groups quite distinct from that of
Chordonia. It is only far down at the common root of
group of Cœlomati, that we assume a common source
these various tribal forms. (Cf. Tables XVIII. and XI
It is especially necessary to remember that there is no dir
blood-relationship between Vertebrates and Articula
Animals.

The Articulated Animals (*Arthropoda*), to which
most comprehensive of all classes of animals, that of Insec
and also the Spiders, Centipedes, as well as the Crabs,
Crustaceans, belong, are descendants of articulated Worm
the nearest allies of which are the extant Ringed Worm
(*Annelida*). The tribe of Star-animals (*Echinoderma*)
which includes the Star-fishes, Sea-lilies, Sea-urchins, an
Sea-cucumbers, must also have descended from similar articu
lated Worms.[118] The parent-form of the Soft-bodied Animal
(*Mollusca*), which include the Cuttles, Snails, Mussels, an
Lamp-shells, must also be sought among the Worms. Bu
the Cœlomati, from which these three higher animal tribe
originated, differed entirely in character from the Chord
animals. Unlike the latter, they never developed a not
chord. In them, the anterior section of the intestinal tub
was never modified into a gill-body with gill-openings; no
were the upper throat-ganglia developed into a medullar
tube. In a word, in Articulated Animals, Star-animals, an
Soft-bodied Animals, as well as in their ancestors amon
the Blood-bearing Worms, the typical structural peculiar
ties which are exclusively characteristic of the vertebra
tribe and of their immediate invertebrate progenitors, we
never present. Thus the great majority of all animals a

no way the subject of our further investigations, which only concerned with the Vertebrates.

The development of the Vertebrates from the Inverte-ates most nearly related to them, the Chorda-Animals, curred millions of years ago, during the Archilithic Epoch. ee Table XII., p. 11.) This is unmistakably shown by e fact that the most recent sedimentary rock-strata hich were deposited during that immense period of time, e higher layers of the Upper Silurian formation, contain mains of fossil Fishes (Primitive Fishes, *Selachii*). As ese Fishes, although they belong to the lowest stage of e Skulled Animals (*Craniota*), yet possess a compara-vely high organization, and as they must necessarily have een preceded by a long progressive series of lower Skull-ss Vertebrates, we must attribute the origin of the oldest kull-less Animals (*Acrania*) from the Chorda-animals to much earlier part of the Archilithic Epoch. Therefore, ot only all the invertebrate ancestors of our race, but also e earliest form of our vertebrate progenitors must have veloped in that primordial time, which includes the urentian, Cambrian, and Silurian Periods. (Cf. Tables III., XIV., and XVI., pp. 12, 19, 44.)

Unfortunately, Palæontology can give us absolutely no formation with regard either to the structure of our oldest rtebrate ancestors, or to the time of their appearance; r their bodies were as soft and as destitute of hard rts capable of fossilization, as were the bodies of all r preceding invertebrate ancestors. It is, therefore, not rprising, but quite natural, that we find no fossil mains of the former in the Archilithic formations. The shes in which the soft cartilaginous skeleton was partly

modified into hard bone, are the earliest Vertebrates ca of leaving petrified records of their existence and struct

Fortunately, this want is more than counterbala by the much more important testimony of Compar Anatomy and Ontogeny, which henceforth form safest guides within the Vertebrate pedigree. Thank the classic researches of Cuvier, Johannes Müller, Hu and especially of Gegenbaur, we are in possession of extensive and instructive records of creation in this important branch of tribal history, that we can prov least the more significant features in the development of Vertebrate ancestors, with the most gratifying certainty

The characteristic peculiarities by which Vertebr in general are distinguished from all Invertebrates, eng our attention some time ago, when we examined the struc of the ideal Primitive Vertebrate (Figs. 52–56, p. 256). most prominent characters were as follows: (1) the forma of the notochord between the medullary and intestinal tu (2) the differentiation of the intestinal tube into an ante gill-intestine and a posterior stomach-intestine; (3) inner articulation, or formation of metamera. The Ve brates share the first two qualities with the larval Ascid and with the Chorda-animals; the third quality is enti peculiar to them. Accordingly, the most important st tural advance, by which the earliest vertebrate forms ori ated from the most nearly allied Chorda-Animals, consi in an internal metameric structure. This showed it first most distinctly in the articulation of the musc system, which broke up on the right and left into a se of consecutive muscular plates. At a later period articulation declared itself prominently in the skeleton,

s and blood-vessel systems. As we have already his process of articulation, or metameric formation, essentially be regarded as terminal germination. distinct trunk-segment, or metameron, represents an dual. Thus the Vertebrates with their internal ntation stand in a similar relation to their inarticulate tebrate ancestors, the Chorda Animals, as do the out- y segmented Ringed Worms (*Annelida*) and Articu- Animals (*Arthropoda*) to the simple inarticulate ns from which they originated.

he tribal history of Vertebrates is rendered much more igible by the natural classification of the tribe which posed first in my *Generelle Morphologie* (1866), and vards improved in many ways in "The Natural History eation" (Chap. XX., p. 192, etc.). In accordance with existing Vertebrates must be divided into at least classes, as follows:—

STEMATIC SURVEY OF THE EIGHT CLASSES OF VERTEBRATES.

-less (*Acrania*)			1. Tube-hearted	1. Leptocardia
d a	a. Single-nostrilled (*Monorhina*)		2. Round-mouths	2. Cyclostoma
	b. Double-nostrilled *Amphirhina*	I. Amnion-less *Anamnia*	3. Fishes	3. Pisces
			4. Mud-fishes	4. Dipneusta
			5. Amphibians	5. Amphibia
		II. With Amnion *Amniota*	6. Reptiles	6. Reptilia
			7. Birds	7. Aves
			8. Mammals	8. Mammalia

he whole Vertebrate tribe may primarily be divided the two main sections of the Skull-less and the ed Vertebrates. Of the earlier and lower section, that Skull-less (*Acrania*), the Amphioxus is alone extant. e more recent and higher section, the Skulled (*Cra-*), belong all other existing Vertebrates up to Man. The

Craniota branched off from the Acrania, as these did the Chorda Animals. Our exhaustive study of the Comp tive Anatomy and Ontogeny of the Ascidian and Amphioxus have already afforded proof of this relation. Chapters XIII. and XIV., and Plates X. and XI. with explanations.) I will only repeat, as the most impor fact, that the Amphioxus develops from the egg in exa the same way as the Ascidian. In both, the original l gastrula (Figs. 4 and 10) originates in an exactly sim manner, by primordial cleavage from the simple parent (Figs. 1 and 7). From this originates that remarkable la which develops a medullary tube on the dorsal side of intestinal tube, and between the two a notochord. A later period, both in the Ascidian and in the Amphioxus intestinal tube differentiates into an anterior gill-intes and a posterior stomach-intestine. In accordance with fundamental principle of Biogeny, from these very impor facts we may deduce the following statement of great ph genetic importance: the Amphioxus, the lowest Vertel form, and the Ascidian, the most nearly allied Invertel form, have both descended from one single extinct W form, which must have possessed the essential structu the Chorda Animals.

The Amphioxus, as has already been often show of extreme importance; not only because it thus fills great gap between the Invertebrates and the Vertebr but also because it represents, at the present time, typical Vertebrate in its simplest form; and becaus directly affords the best standpoint from which to exa the gradual historic evolution of the whole tribe. If structure and germ-history of the Amphioxus were

wn to us, the whole subject of the development of Vertebrate tribe, and thus of our own race, would be veloped in an impenetrable veil. The accurate anatomical d ontogenetic knowledge of the Amphioxus, attained ring the last few years, has alone pierced that heavy veil, merly supposed to be impenetrable. If the Amphioxus is npared with the developed Man or any other of the her Vertebrates, a great number of striking dissimilarities ll be seen. The Amphioxus has no specialized head, no in, no skull, no jaws, no limbs; it is without a central-d heart, a developed liver and kidneys, a jointed vertebral umn; every organ appears in a much simpler and more mitive form than in the higher Vertebrates and in Man. Table X., vol. i. p. 466.) And yet, in spite of all these ious deviations from the structure of other Vertebrates, Amphioxus is a genuine, unmistakable Vertebrate; l if, instead of the developed Man, the human embryo an early period of its Ontogeny is compared with Amphioxus, we shall find perfect parallelism between two in all essential points. (Cf. Table IX., vol. i. p. 465.) is highly important parallelism justifies the conclusion t all the Skulled Animals (*Craniota*) have descended m a common primæval parent-form, the structure of ich was essentially that of the Amphioxus. This parent-m, the earliest Primitive Vertebrate, possessed the uliar characters of the Vertebrates, and yet was without those important peculiarities that distinguish the Skulled imals from the Skull-less. Although the Amphioxus ap-rs peculiarly organized in many respects, and although nay not be regarded as an unmodified descendant of the mitive Vertebrate, yet it must have inherited from the

latter the distinguishing characteristic features alre mentioned. We cannot therefore say that the Amphioxu the progenitor of the Vertebrates; but we may certainly that the Amphioxus of all known animals is nearest all to this progenitor; both belong to the same limited fam group, to the lowest Vertebrate class, that of the Skull-l Animals (*Acrania*). In the human pedigree, this gro forms the ninth stage of the ancestral chain, the first amo Vertebrate ancestors. From this Skull-less group v developed the Amphioxus on the one side, and on the ot the parent-form of the Skulled Animals (*Craniota*).

The comprehensive group of the Skulled Anim includes all known Vertebrates, with the single exc tion of the Amphioxus. All these Skulled Anim possess a distinct head, inwardly specialized from trunk, and this contains a skull, enclosing a brain. T head also carries three of the higher sense-organs, which partially wanting in the Skull-less Animals (nose, ears, eyes). At first, the brain appears in a very simple form an anterior bladder-like extension of the medullary t (Plate XI. Fig. 16, m_1). This, however, is soon distributed several tranverse grooves—first into three, and afterwa into a series of five consecutive brain-bladders. In formation of the head, skull, and brain, together with higher sense-organs, lies the most essential advance m by the skulled parent-form beyond its skull-less ancest Other organs, however, also soon rose to a higher gr of development; a compact centralized heart appeare more perfect liver and kidneys; and in other directi also important advance was made.

The Skull-less Animals may be primarily subdivi

differing main sections, that of the Single-nostrils *na*), and that of the Double-nostrils (*Amphirhina*). rmer there are but very few extant forms, which Round-mouths (*Cyclostoma*). These are, however, nterest, because in their whole structure they are iate between the Skull-less Animals and the Double- *Amphirhina*). Their organization is much higher t of the Skull-less Animals, much lower than that Double-nostrils; they thus form a very welcome etic link between those two divisions. We may represent them as a special, tenth stage in the ncestral series.

ew existing species of the class of Round-mouths are ed into two different orders, which are distinguished Hags and the Lampreys. The Hags (*Myxinoides*) g, cylindrical, worm-like bodies. Linnæus classed ong Worms, but later zoologists have placed them, es among the Fishes, sometimes Amphibians, and ith Molluscs. The Hags live in the sea and are parasitic on Fishes, into the skin of which they e by means of their round sucking mouths and thed tongues. They are occasionally found in the ity of Fishes—for example, of the Cod and Stur- aving penetrated to the interior in their passage the skin. The second order, that of the Lampreys *yzontes*), includes those well-known "Nine eyes," at the seaside; the little river Lamprey (*Petro- luviatilis*) and the large sea Lamprey (*Petromyzon* , Fig. 190).

animals included in the two groups of the *Myxi-* and the *Petromyzontes*, are called Round-mouths

(*Cyclostoma*), from the fact that their mouth forms a circular or semi-circular opening. The upper and under jaws, which appear in all the higher Vertebrates, are completely wanting in the Round-mouths, as in the Amphioxus. All other Vertebrates are therefore distinguishable from them as "Jaw-mouthed" (*Gnathostomi*). The Round-mouths may also be called "Single-nostrils" (*Monorhina*), because they have but a single nasal tube, while the Gnathostomi are all furnished with a pair of nasal cavities, a right and a left nose-cavity ("Double-nostrilled," *Amphirhina*). But in addition to these peculiarities, the Jaw-mouths are also distinguished by many other remarkable structural arrangements, and are further removed from the Fishes than the latter are from Man. They must, therefore, evidently be regarded as the last remnant of a very old and very low class of Vertebrates, which are far below the structural stage of a genuine Fish. To mention here briefly only the most important, the Round-mouths are entirely without any trace of limbs. Their slimy skin is quite naked and smooth, without scales. They are wholly destitute of a bony skeleton. The inner skeleton axis is a very simple inarticulate notochord, like that of the Amphioxus. In the Lampreys alone a rudimentary articulation is indicated by the fact that upper arches appear in the vertebral tube proceeding from the notochord sheath. At the anterior end of the chorda a skull is developed in its very simplest form. From the notochord sheath proceeds a small soft-membraneous skull capsule, which becomes partly cartilaginous: this capsule encloses the brain. The important apparatus of the gill-arches, the tongue-bone, etc., which is inherited by all Vertebrate

shes to Man, is wholly wanting in
ind-mouths. They have, indeed, a
l, cartilaginous gill-skeleton, but this
e different morphological significance.
ther hand, in them we meet, for the
e, with a brain, that important
rgan, which has been transmitted
Single-nostrils up to Man. It is true
he Round-mouths the brain appears
s a very small and comparatively
ant swelling of the spinal chord; at
mple bladder (Plate XI. Fig. 16, m_1),
terwards separates into five consecu-
n-bladders, as in the brains of all
reathers. These five simple primitive
dders, which reappear in a similar
he embryos of all higher Vertebrates,
hes up to Man, and which undergo
complex modification, remain in the
ouths, in a very low and undifferen-
ge of development. The histological
ry structure of the nervous system is
h more imperfect than in other Verte-
While in the latter the organ of
lways has three semi-circular canals,
ampreys it has but two, and in the
t one. In most other points also,
nization of the Round-mouths is

0.—The large Sea-lamprey (*Petromyzon mari-*
reduced in size. A series of seven gill-open-
ible below the eye.

much simpler and more imperfect, as, for instance, in structure of the heart, the circulatory system, and kidneys. In them, as in the Amphioxus, the anter portion of the intestinal canal does, indeed, form respirat gills; but these respiratory organs are developed in a ve peculiar way: in the form of six or seven little pouches, sacs, which lie on both sides of the anterior intestine a communicate with the throat (*pharynx*) by inner openin and by outer ones with the external skin. This is a ve peculiar formation of the respiratory organs, quite ch racteristic of this class of animals. They have therefo been called the "Pouch-gills" (*Marsupobranchii*). Th absence of one very important organ found in the Fishe the swimming-bladder, from which the lungs of the highe Vertebrates have developed, should be especially noticed.

In their germ-history, as in their whole anatomical structure, the Round-mouths present many peculiarities. They are even peculiar in the unequal cleavage of the egg, which most nearly approaches that of the Amphibians (Fig. 31, vol. i. p. 203). This results in the formation of a Hood-gastrula, like that of Amphibians (Plate II. Fig. 11). From this develops a very simple organized larval form, which is closely allied to the Amphioxus, and which, for that reason we examined and compared with the latter (vol. i. p. 428 and Plate VIII. Fig. 16). The gradual germ-evolution o these larvæ of the Round-mouths explains very clearly an unmistakably the gradual evolution of the Skulled from th Skull-less class of Vertebrates. At a later period, from this simple Lamprey larva is developed a blind and tooth less larval form, which is so very different from the matur Lamprey that, until twenty years ago, it was generall

cribed as a peculiar form of fish under the name of *mocœtes*. By a further metamorphosis this blind and thless Ammocœtes is transformed into the Lamprey with es and teeth (*Petromyzon*).[147]

Summing up all these peculiarities in the structure and bryology of the Round-mouths, we may assert that the dest Skulled Animals, or *Craniota*, diverged in two lines; e of these lines has continued up to the present time t little modified; it is represented by the Cyclostoma, Monorhina, forming a collateral line which has made t little progress, but has remained at a very low stage of velopment. The other line, the direct line in the pedigree the Vertebrates, advanced in a straight line to the Fishes, d by new adaptations attained many important improvents.

In order rightly to appreciate the phylogenetic signiance of interesting remnants of primæval groups of imals, such as the Round-mouths, it is necessary to study inutely their various peculiar characters philosophically d with the aid of Comparative Anatomy. A careful stinction must be drawn between the hereditary chacters which have been accurately transmitted to the resent day by heredity from common, primæval ancestors, w extinct, on the one hand; and, on the other, those ecial adaptive peculiarities which the existing remnant that primæval group have, in the course of time, gained condarily by adaptation. To the latter class belong, r example, in the Round-mouths, the peculiar formation the single nostril and the round sucking mouth; as ell as special structural arrangements of the epidermis d the pouch-shaped gills. But, on the other hand, to the

former class of characteristics, which alone have any p genetic significance, belong the primitive formation c vertebral column and the brain, the absence of the s ming-bladder, of jaws, limbs, etc.

In the animal system, the Round-mouths are us classed among Fishes; but that this is quite incorr apparent from the simple fact that, in all important prominent structural peculiarities, they are further rem from the Fishes than the Fishes are from the Mammals from Man.

CHAPTER XVIII.

THE PEDIGREE OF MAN.

III. From the Primitive Fish to the Amniotic Animal.

Comparative Anatomy of the Vertebrates.—The Characteristic Qualities of the Double-nostrilled and Jaw-mouthed: the Double-Nostrils, the Gill-arch Apparatus, with the Jaw-arches, the Swimming-bladder, the Two Pairs of Limbs.—Relationship of the Three Groups of Fishes: the Primitive Fishes (*Selachii*), the Ganoids (*Ganoides*), the Osseous Fishes (*Teleostei*).—Dawn of Terrestial Life on the Earth.—Modification of the Swimming-bladder into the Lungs.—Intermediate Position of the Dipneusta between the Primitive Fishes and Amphibia.—The Three Extant Dipneusta (*Protopterus, Lepidosiren, Ceratodus*).—Modification of the Many-toed Fin of the Fish into the Five-toed Foot.—Causes and Effects of the latter.—Descent of all Higher Vertebrates from a Five-toed Amphibian.—Intermediate Position of the Amphibians between the Lower and Higher Vertebrates.—Modification or Metamorphosis of Frogs.—Different Stages in Amphibian Metamorphosis.—The Gilled Batrachians (*Proteus* and *Axolotl*).—The Tailed Batrachians (Salamanders and Mud-fish).—Frog Batrachians (Frogs and Toads).—Chief Group of the Amnion Animals, or *Amniota* (Reptiles, Birds, and Mammals).—Descent of all the Amniota from a Common Lizard-like Parent-form (*Protamnion*).—First Formation of the Allantois and of the Amnion.—Branching of the Amnion Animals in Two Lines: on the one side, Reptiles (and Birds), on the other side, Mammals.

"The imagination is an indispensable faculty; for it is that which, by forming new combinations, occasions important discoveries. The naturalist needs both the discriminating power of abstract reason, and the generalizing power of the imagination, and that the two should be harmoniously inter-

related. If the proper balance of these faculties is destroyed, the nat is hurried into chimerical fancies by his imagination; while the sa leads the gifted naturalist of sufficient strength of reason to th important discoveries."—JOHANNES MÜLLER (1834).

THE further we proceed in human tribal history, the rower does that part of the animal kingdom become w which we must look for extinct ancestors of the hu race. At the same time, the evidence as to the histo the evolution of our race given by what we have calle records of creation, the evidence of Ontogeny, of Com tive Anatomy, and of Palæontology, grows constantly extensive, complete, and trustworthy. It is ther natural that Phylogeny should assume a more definite the nearer we approach the higher and the highest s of the animal kingdom.

Comparative Anatomy especially has done far mor our knowledge of these higher stages of evolution i animal kingdom than for the lower. This impo science, which aims at a true philosophy of organic f has made greater progress in the Vertebrate tribe than i section of the Invertebrate. Cuvier, Meckel, and Joh Müller had already laid a deep and extensive found and now the Comparative Anatomy of Vertebrate recently been powerfully advanced by the admirable i tigations of Owen and Huxley, and, especially, has perfected to such a degree by the unsurpassed labo Gegenbaur, that it now forms one of the strongest su of the Theory of Descent. Relying on the evidence furnished, we can now, with a great degree of cert recognize the most important outlines of the series of and the ramifications of the Vertebrate pedigree.

at part of the animal kingdom with which we are oncerned has become so narrow, even before we have he Archilithic Epoch, that but a single one of the tribes of the animal kingdom forms the object of our . Even within this tribe we have passed the lowest , and have risen above the Skull-less (*Acrania*) and ble-nostrilled Vertebrates (*Monorhina*), to the class of es. The latter are the first of the great main division ertebrates distinguished by mouths with jaws and by ble nostrils (*Amphirhina*, or *Gnathostoma*). From Fishes tart again, as from that class of Vertebrates which are bitably shown by Comparative Anatomy and Ontogeny e the ancestral class of all higher Vertebrates, all Amhina. Of course no existing Fish can be regarded as direct parent-form of the higher Vertebrates. But it is lly certain that from a common extinct Fish-like nt-form we may trace all those Vertebrates from Fishes to Man, which are included under the name of Amhina. If this primæval parent-form were extant, we ld undoubtedly describe it as a genuine Fish and class ong Fishes. Fortunately, the Comparative Anatomy Classification of the Fishes has been so far advanced nks to the labours of Johannes Müller and Gegenbaur) we can very clearly distinguish these most important interesting genealogical relations.

In order correctly to understand the human pedigree in the Vertebrate tribe, it is very important to bear in d the distinguishing characteristics, separating Fishes all the other Double-nostrils (*Amphirhina*) from gle-nostrilled and Skull-less Animals (*Monorhina* and *ania*). These very distinguishing characteristic marks

Fishes have in common with all other Double-nostrils to Man, and it is on this parallelism that we found claim of relationship to Fishes. (Cf. Table X., vol. p. 466.) The following characters of the Double-nost must be especially indicated as the systematic anatom features of the highest importance: (1) the double struct of the nose; (2) the internal gill-arch apparatus, togeth with the jaw-arches; (3) the swimming-bladder, or lung and (4) the two pairs of limbs.

As to the nasal structure, on which is based the distin tion of the Single-nostrils (*Monorhina*) from the Doub nostrils (*Amphirhina*), it is certainly significant that even Fishes the earliest rudiment of the nose consists of two e tirely distinct lateral grooves or pits in the outer surface the head, just as is the case in the embryo of Man and of a higher Vertebrates. On the other hand, in Single-nostril and Skull-less Vertebrates the first rudiment of the nose i from the first, a single pit in the centre of the forehea region. No less important is the higher development of th skeleton of the gill-arch and of the jaw apparatus connecte with it, as it occurs in all Double-nostrils from Fishes t Man. It is true that the primitive modification of th anterior intestine into the gill-intestine, which occurs eve in Ascidians, is developed in all Vertebrates from one simp rudiment; and in this respect the gill-openings, which all Vertebrates and also in Ascidians pierce the wall of th gill-intestine, are quite characteristic. But the extern framework of the gills, which in all Skull-less and Singl nostrilled Animals (*Acraniota* and *Monorhina*) suppor the gill-body, is displaced in all Double-nostrils (*Ampl rhina*) by an internal gill-skeleton which replaces the form

This internal gill-support consists of a consecutive series of cartilaginous arches, which are situated between the gill-openings within the wall of the throat (pharynx), and extend round the throat. The foremost of these pairs of gill-arches changes into the jaw-arch (maxillary arch), which gives rise to the upper and lower jaws.

A third essential character by which all Double-nostrils are well distinguished from all those lower Vertebrates which we have already considered, is the formation of a blind sac which protrudes from the anterior portion of the intestinal canal, and which in the Fishes becomes the air-filled swimming-bladder (Plate V. Fig. 13, *lu*). As this organ, in proportion as it contains a greater or less quantity of air, or in proportion as this air is more or less compressed, imparts a higher or lower specific gravity to the Fish, it acts as a hydrostatic apparatus. By this means the Fish can rise or sink in the water. This swimming-bladder is the organ from which the lung of higher Vertebrates has developed. The fourth and last main character of Double-nostrils is the presence of two pairs of extremities or members in the primitive arrangement of the embryo; a pair of fore limbs, which in Fishes are called pectoral fins (Fig. 191, *v*), and a pair of hind limbs, which in Fishes are called ventral fins (Fig. 191, *h*). The Comparative Anatomy of these fins is of supreme interest, because they contain the rudiments of all those parts of the skeleton which, in all the higher Vertebrates up to Man, form the skeleton or support of the extremities of the fore and hind limbs. In Skull-less and Single-nostrilled Animals there is, on the contrary, no trace of these extremities. In addition to these four most important main characters of the Amphi-

rhina, we might further mention the presence of a sy[illegible] pathetic nerve-system, a spleen, a ventral salivary gland[illegible] organs which are not represented in the lower Vertebr[illegible] already considered. All these important parts have tr[illegible] mitted themselves from Fishes up to Man, and from th[illegible] circumstance alone it is evident how wide a chasm se[illegible] rates the Fishes from the Skull-less and Single-nostr[illegible] Animals (*Acraniota* and *Monorhina*). Fishes and [illegible] possess all these characters in common (Table X.).

Turning now to consider the Fish class in greater de[illegible] we may divide it primarily into three main groups, or [illegible] classes, the genealogies of which are evident. The [illegible] and most ancient group is that of the Primitive Fishe[illegible] (*Selachii*), the best-known extant representatives of which are the members of the much-varied orders of Sharks and Rays (Figs. 191, 192). These are followed by a series of further developed Fish forms, by the sub-class of Mucous Fishes (*Ganoides*). The greater number of these have long been extinct, and only very few living representatives are known; these are the Sturgeon and Huso of European seas, the Polypterus of African, and the Lepidosteus and Amia of American rivers. The earlier abundance of forms belonging to this interesting group is, however, proved by the abundance of their fossil remains. From these Mucous Fishes originated the third sub-class, that of the Osseous Fishes (*Teleostei*), to which belong most extant Fishes, especially nearly all our river fish. Comparative Anatomy and Ontogeny very clearly show that the Ganoids sprang from the Selachii, just as the Teleostei sprang from the Ganoids. But, on the other hand, a second side-line, or rather the main ascending line of the Vertebrate tribe,

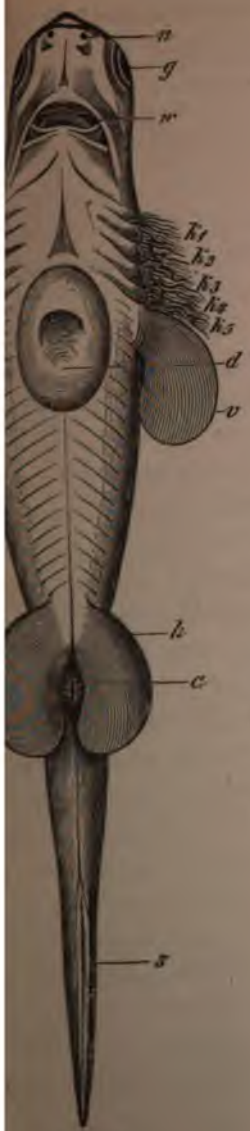


Fig. 191.

Fig. 192.

FIG. 191.—Embryo of a Shark (*Scymnus lichia*), seen from ventral sid *v*, pectoral fins (in front of these five pairs of gill-openings); *h*, ventral fin *a*, anal opening; *s*, tail fin; *k*, external gill-tufts; *d*, yelk-sac (the great part of this has been removed); *g*, eye; *n*, nose; *m*, mouth fissure.

FIG. 192.—Developed Man-shark (*Carcharias melanopterus*), seen fro the left side: r_1 first, r_2 second dorsal fin; *s*, tail fin; *a*, anal fin; *v*, pectora fins; *h*, ventral fins.

developed in another direction from the Primitive Fishes this line leads upward through the Dipneusta group to th important class of Amphibia.

This significant relationship between the three grou of Fishes has been placed beyond all doubt by the r searches of Gegenbaur on the subject. The lucid discussio on the "systematic position of the Selachii" which th author inserted in the introduction to his classic study the "head skeleton of the Selachii," must be regarded definitely proving this important relation.[148] In Primiti Fishes (*Selachii*), however, the scales (skin appendage and the teeth (jaw appendages) are identical in formati and structure, while in the other two groups of Fish (Mucous and Osseous Fishes) these organs have alrea become distinct and differentiated. Moreover, in Primiti Fishes, the cartilaginous skeleton (the vertebral colun and the skull, as well as the members) is of the simple and most primitive nature, of which the bony skeleto of Mucous and Osseous Fishes must be regarded as modification. It is true that in certain respects (in t structure of the heart and of the intestinal canal) Muco Fishes fully coincide with Primitive Fishes, and differ fro Osseous Fishes. But a comparative review of all t anatomical relations plainly shows that the Mucous Fish constitute a connecting group between Primitive a

Osseous Fishes. The Primitive Fishes (*Selachii*) form the most ancient and original group of Fishes. From these, in one direction, all other Fishes have developed; the Mucous Fishes first, which, at a much later period (in the Jurassic, or the Chalk Period), gave rise to the Osseous Fishes. In another direction, the Primitive Fishes gave rise to the parent-forms of the higher Vertebrates, directly to the Dipneusta, and thus to Amphibians. Regarding the Selachii as forming the eleventh stage in our pedigree, these would be followed by the Dipneusta group as the twelfth stage, and by the Amphibian group as the thirteenth stage.

The advance effected in the development of the Mud-fishes (*Dipneusta*) from the Primitive Fishes is of great moment, and is connected with a very noticeable change, which took place in the beginning of the Palæozoic, or Primary Period in organic life as a whole. For the very numerous fossil remains of plants and animals which are now known to belong to the first three epochs of the history of the earth—to the Laurentian, the Cambrian, and the Silurian Periods, are exclusively those of aquatic plants and animals. From this palæontological fact, taken in connection with certain weighty geological and biological considerations, we may infer, with tolerable certainty, that at that time no land animals yet existed. During the whole of the enormous Archizoic Period—during many millions of years—the living population of our globe were all water-dwellers: a very remarkable fact, when it is remembered that this period embraces the larger half of the entire organic history of the earth. The lower animal tribes are even now exclusively, or with very few exceptions, aquatic. But during the Archizoic, or Primordial Epoch, the higher animal tribes

continued exclusively adapted to aquatic habits of life. I was not till later that they adopted a land life. The earlies fossils of terrestrial animals occur in the Devonian strata which were deposited in the beginning of the second great division of the earth's history (the Palæozoic Epoch). They increase greatly in number in the deposits of the Coal and Permian Periods. Even in these early formations many terrestrial and air-breathing species, both of the Arthropod and of the Vertebrate tribe, occur; while their aquatic ancestors of the Silurian Period breathed nothing but water. This physiologically significant modification of the mode of respiration is the most influential change that affected the animal organism in the transition from water to dry land. In the first place it caused the development of an air-breathing organ, the lung, the water-breathing gills having previously acted as respiratory organs. Simultaneously, however, it effected a remarkable change in the circulation of the blood and in the organs connected with this; for these are always most closely correlated with the respiratory organs. In addition to these, other organs also either in consequence of more remote correlation with the respiratory organs, or in consequence of new adaptations were more or less modified.

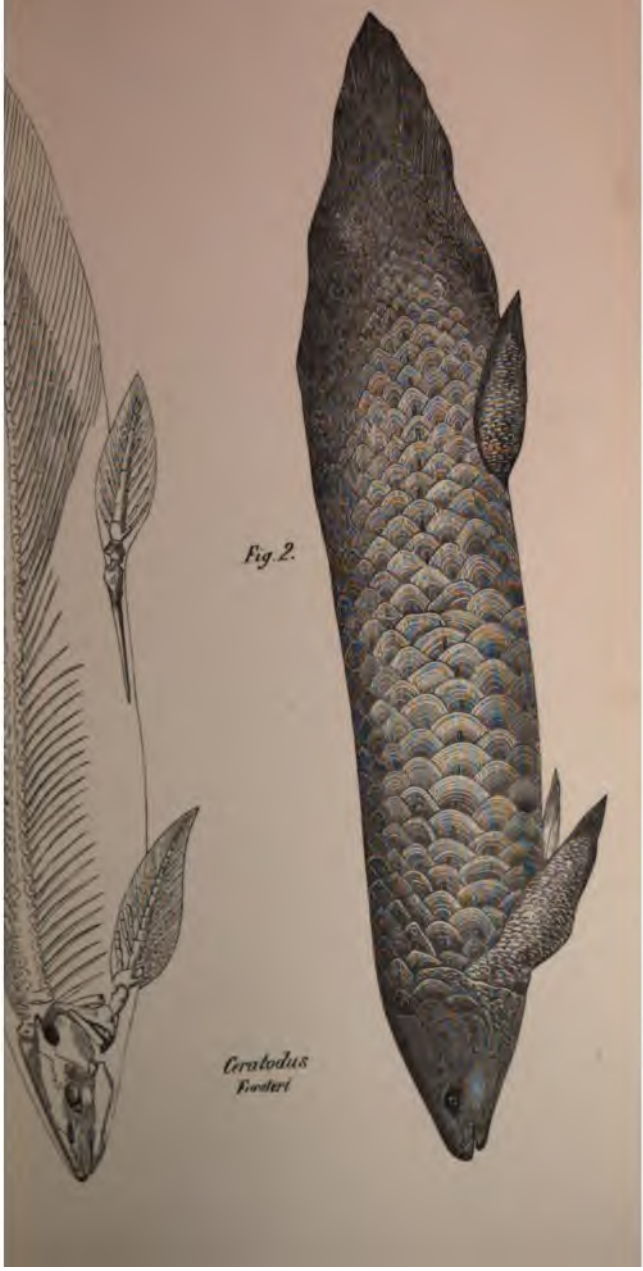
Within the Vertebrate tribe it was undoubtedly a branch of the Primitive Fishes (*Selachii*) which, during the Devonian Period, made the first successful effort to accustom itself to terrestrial life and to breathe atmospheric air. In this the swimming-bladder was especially of service, for it succeeded in adapting itself to respiration of air, and so became a lung. The immediate consequence of this was the modification of the heart and nose. While true Fishes

have only two blind nose-pits on the surface of the head, these now became connected with the mouth-cavity by an open passage. A canal formed on each side, leading directly from the nose-pit into the mouth-cavity, and thus even while the mouth-opening was closed the necessary atmospheric air could be introduced into the lungs. While, moreover, in all true Fishes the heart consists simply of two compartments, an auricle, which receives the venous blood from the veins of the body, and a ventricle, which forces this blood through an arterial expansion into the gills, the auricle, owing to the formation of an incomplete partition wall, is now divided into a right and a left half. The right auricle alone now received the venous blood of the body, while the left auricle received the pulmonic venous blood passing from the lungs and the gills to the heart. The simple blood-circulation of the true Fishes thus became the so-called double circulation of the higher Vertebrates; and this development resulted, in accordance with the laws of correlation, in further progress in the structure of other organs.

The vertebrate class, which thus first adapted itself to the habit of breathing air, and which originated from a branch of the Selachii, are called Mud-fishes (*Dipneusta*), or Double-breathers, because, like the lowest Amphibia, they retain the earlier mode of breathing through the gills, in addition to the newly acquired lung-respiration. This class must have been represented by numerous and diverse genera during the Palæolithic Epoch (during the Devonian, Carboniferous, and Permian Periods). As, however, the skeleton is soft and cartilaginous, like that of the Selachii, they naturally left no fossil remains. The hard teeth of

single genera (*Ceratodus*) could alone endure; these
for instance, in the Trias. At the present time ther
only three extant genera of this whole class: *Protop*
annectens, in the rivers of tropical Africa (White
Niger, Quillimane, etc.); *Lepidosiren paradoxa*, in tr
South America (in the tributaries of the Amazon);
Ceratodus Fosteri, in the swamps of Southern Aus
(Plate XII.).[149] This wide distribution of the three isc
descendants of the class is alone sufficient to prove
they are the last remnants of a group which was forı
very widely developed. The whole structure of
bodies shows that the group to which they belong form
transition between Fishes and Amphibia. The direct
sitional structure between the two classes is so cl
expressed in the whole organization of these curious ani
that zoologists yet dispute whether the Dipneust
Fishes or Amphibia. Some well-known zoologists still
them among Amphibia, while they are usually p
among Fishes. In fact, the characters of both the c
are so united in the Dipneusta that the answer tc
question as to their nature depends entirely upon the n
ing attached to the terms "Fish" and "Amphibian."
their mode of life they are true Amphibia. During
tropical winter, in the rainy season, they swim in the
like Fishes and inhale water through the gills. Durin
dry season they burrow in the mud as it dries up
during that period breathe air through lungs, like
phibians and higher Vertebrates. In this two-fold res
tion they do, it is true, coincide with the lower Ampl
and stand far above Fishes. Yet, in most other chara
they more nearly resemble the latter, and stand belov

PLATE XII.



former. Their external appearance is entirely like that of Fishes.

The head of the Dipneusta is not distinct from the trunk. The skin is covered with large fish-scales. The skeleton is soft, cartilaginous; its development has been arrested at a very low stage, just as in the lower Primitive Fishes. The notochord is retained entire. The two pairs of limbs are very simple fins of primitive structure, like those of the lowest Primitive Fishes. The structure of the brain, of the intestinal tube, and the sexual organs, is also as in Primitive Fishes. The Dipneusta, or Mud-fishes, have, therefore, by heredity, accurately retained many features of a lower organization derived from our primæval Fish ancestors, while their adoption of the habit of breathing air through lungs introduced a great advance in the vertebrate organization.

Moreover, the three extant Mud-fishes differ a good deal from one another in important points of structure. The Australian Mud-fish (*Ceratodus*), which was first described at Sidney in 1870 by Gerard Krefft, and which attains a length of six feet, appears in an especial degree to represent a primæval and very conservative animal form (Plate XII.). This is especially true of the structure of its simple lung, and of its fins, which contain a pinnate skeleton. In the African Mud-fish (*Protopterus*), on the contrary, and in the American form (*Lepidosiren*) the double lung is present, as in all higher Vertebrates; nor is the fin-skeleton pinnate. In addition to the internal gills, Protopterus has also external gills, which are wanting in Lepidosiren. Those unknown Dipneusta, which were among our direct ancestors, and which formed the connecting link between the Selachii

TABLE XX.

Systematic Survey of the Phylogenetic Classification of Vertebrates.

I. Skull-less (Acrania), or Tube-hearted (Leptocardia).
Vertebrates without a specialized head, skull, brain, or centralized h

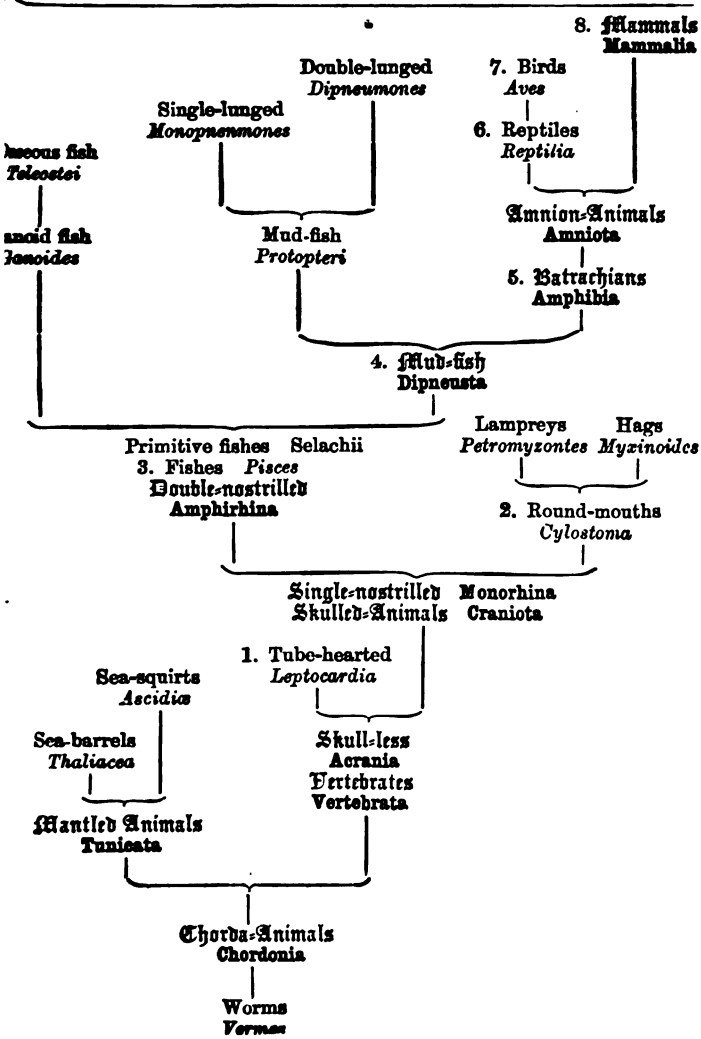
1. Skull-less Acrania	**I. Tube-hearted** *Leptocardia*	**1. Lancelets**	**1. Amphioxid**

II. Animals with skulls (Craniota) and with centralized hearts (Pachyc
Vertebrates with specialized head, with skull and brain, and with centralized heart.

Main-classes of the Skulled Animals.	*Classes of the Skulled Animals.*	*Sub-classes of the Skulled Animals.*	*Systematic of the Sub-class*
2. Single-Nostrilled Monorhina	II. Round mouths *Cyclostoma*	2. Hags, or Mucous Fish	2. Hyperot (Myxinoi
		3. Lampreys	3. Hyperos (Petromy
3. Non-amnionate Anamnia	III. Fishes *Pisces*	4. Primitive Fish	4. Selachii
		5. Ganoid Fish	5. Ganoide
		6. Osseous Fish	6. Teleoste
	IV. Mud-fishes *Dipneusta*	7. Single-lunged	7. Monopne
		8. Double-lunged	8. Dipneun
	V. Batrachians *Amphibia*	9. Mailed Batrachians	9. Phractan
		10. Naked Batrachians	10. Lissamp
4. Amnion-Animals Amniota	VI. Reptiles *Reptilia*	11. Lizards	11. Lacertili
		12. Snakes	12. Ophidia
		13. Crocodiles	13. Crocodil
		14. Tortoises	14. Chelonia
		15. Sea-dragons	15. Halisaur
		16. Dragons	16. Dinosau
		17. Flying Reptiles	17. Pterosau
		18. Beaked Animals	18. Anomod
	VII. Birds *Aves*	19. Long-tailed	19. Saururæ
		20. Fan-tailed	20. Carinata
		21. Bush-tailed	21. Ratitæ
	VIII. Mammals *Mammalia*	22. Cloacal Animals	22. Monotre
		23. Pouched Animals	23. Marsupi
		24. Placental Animals	24. Placenta

TABLE XXI.

Pedigree of Vertebrates. (*Cf. Plate XV.*)



[illegible] germ
[illegible] As [illegible] is as yet entir
[illegible] time it will a
[illegible] important [illegible] the [illegible] Histor
[illegible] Vertebrates [illegible] our ancestors.

Very important information of this kind h
supplied by the most Vertebrate class, that of the
[illegible] *Amphibia*, which is directly connected w
[illegible] from which it originated. To this clas
the Axolotl, Salamanders (Plate XIII.), Toads, and
[illegible] after the example of Linnæus all Reptiles,
[illegible] Crocodiles and Tortoises were also classed
Amphibia. But these animals are of a far higher o
[illegible] and in the most important characters of th
[illegible] structure are more nearly allied to Birds
Amphibians. The true Amphibia, on the other h
more nearly allied to the Double-breathers and to P
Fishes: they are also much older than Reptiles.
early as the Carboniferous Period numerous very
developed Amphibia (some of large size) were extant.

the yet extant Amphibians have a smooth and slippery n. The latter, also, are on an average smoother than the mer, and must be regarded as their stunted posterity.

Among the Amphibia of the present time we are, erefore, unable to find any forms that are directly referable the pedigree of the human race, or that are to be re-rded as ancestors of the three higher Vertebrate classes; et, in important points of their internal anatomical struc-ure, and especially in their germ-development, they cor-spond so closely with us, that we are justified in affirming hat between the Double-breathers (*Dipneusta*) on the one and, and the three higher Vertebrate classes (grouped ogether as Amniota) on the other, there existed a series of xtinct intermediate forms which, if we had them before us, ve should class among Amphibia. The whole organization f the extant Amphibia represents a transitional group of his kind. In the important matters of respiration and irculation of the blood, they are still closely allied to the Double-breathers, although in other respects they rise above the latter. This is especially true with respect to the ad-vanced structure of their limbs or extremities. The latter here for the first time appear as feet with five digits. The thorough researches of Gegenbaur have shown that the fins of Fishes, concerning which very erroneous views were pre-viously held, are feet with numerous digits; that is to say, the several cartilaginous or osseous rays, many of which occur in every Fish-fin, correspond to the fingers or digits on the limbs of higher Vertebrates. The several joints of each ray correspond to the several joints of each digit. In the Double-breathers the fin yet retains the same structure as in Fishes, and it was only gradually that the five-toed form of foot,

which occurs for the first time in Amphibians, was devel from this multi-digitate form. This reduction in the nu of the digits from ten to five occurred in those Dipn which must be regarded as the parent-forms of the Amp probably as early as the latter half of the Devonian Pe or, at latest, in the immediately subsequent Carboni Period. Several fossil Amphibia with five digits have a been found in the strata of the latter period. Fossi prints of the same animals are very numerous i Trias (*Cherotherium*).

The great significance of the five digits depends fact that this number has been transmitted fro Amphibia to all higher Vertebrates. It would be imp to discover any reason why in the lowest Amphibia, as as in Reptiles and in higher Vertebrates up to there should always originally be five digits on each anterior and posterior limbs, if we denied that he from a common five-fingered parent-form is the e cause of this phenomenon: heredity can alone accou it. In many Amphibia, certainly, as well as in many Vertebrates, we find less than five digits. But in al cases it can be shown that separate digits have retrog and have finally been completely lost.

The causes which effected the development of th fingered foot of the higher Vertebrates in this Amp parent-form from the many-fingered foot, must certai found in the adaptation to the totally altered fu which the limbs had to discharge during the transitio an exclusively aquatic life to one which was pa terrestrial. While the many-fingered fins of the Fi previously served almost exclusively to propel the

he water, they had now also to afford support to al while creeping upon land. This effected a ion both of the skeleton and of the muscles of . The number of fin rays was gradually lessened, finally reduced to five. These five remaining , however, developed more vigorously. The soft ous rays became hard bones. The rest of the also became considerably more firm. The move- the body became not only more vigorous, but e varied. The separate portions of the skeleton nd consequently those of the muscular system also, ore and more differentiated. Owing to the intimate n of the muscular to the nervous system, the latter rally made marked progress in point of function cture. We therefore find that the brain is very ore developed in the higher Amphibia than in Mud-fishes, and in the lower Amphibia.

rgans which are most modified in consequence of ibious mode of life are, as we have already seen in ble-breathers (*Dipneusta*), those of respiration and circulation of the blood. The first advance in ion necessitated by the transition from aquatic to l habits of life was, of course, the formation of an hing organ, a lung. This developed directly from ming-bladder which these animals had inherited Fishes. At first the function of this organ would subordinate to the more ancient organ, used for the n of water, the gills. Hence we find that the mphibia, the Gilled Amphibia, like the Dipneusta, e greater part of their lives in the water, and that ly they breathe water through gills. It is only

for brief intervals that they rise to the surface of the water or creep out of the water on to the land; and at these times they breathe air through lungs. Some, however, of the Tailed Amphibians, the Axolotl and the Salamander, live exclusively in the water only when young, and afterwards usually remain on land. In the adult state they breathe only air through lungs. This is also the case with the most highly developed Amphibians, the Frog-amphibia (Frogs and Toads); some of the latter have even entirely lost the gilled larval form.[158] The same is true of a few small snake-like Amphibia, the Cæciliæ, which, like earth-worms, live in the ground.

The high degree of interest attached to the natural history of the Amphibian class is especially due to the fact that they hold a position exactly intermediate between the higher and the lower Vertebrates. While the lower Amphibia are in their whole organization directly allied to the Dipneusta and the Fishes, living mostly in the water and respiring water through gills, the higher Amphibia are no less directly related to the Amnion Animals, for, like the latter, they live mostly on land, and breathe air through lungs. But when young the higher forms resemble the lower, and only attain their own higher degree of development after undergoing complete modification. The individual germ-history of most higher Amphibians still accurately reproduces the tribal history of the whole class; and the various stages of modification which were necessitated in certain low Vertebrates by the transition from aquatic to terrestrial habits during the Devonian or Carboniferous Period, are still to be seen every spring in each Frog as it develops from the egg in our ditches and pools.

Like the Tailed Salamanders (Fig. 193), each common Frog emerges from the egg in a larval form, totally different from that of the full-grown Frog (Fig. 194). The short

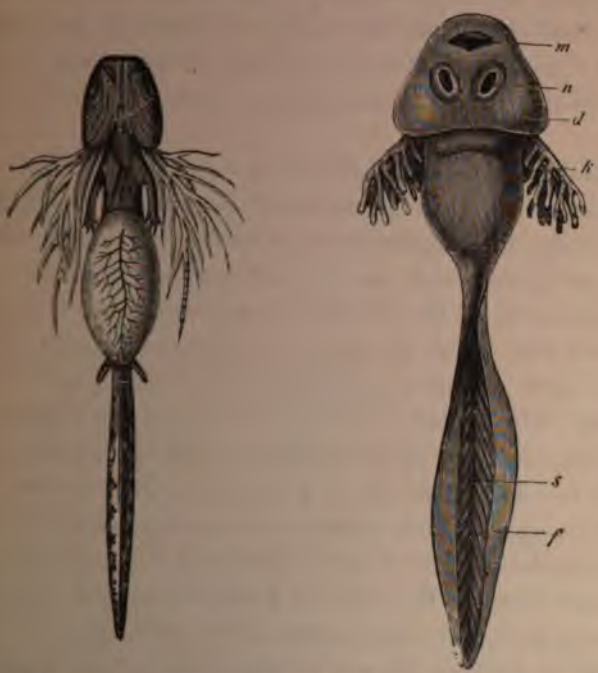


FIG. 193.—Larva of Spotted Land-Newt (*Salamandra maculata*), from e ventral side. In the centre a yolk-sac yet protrudes from the intestine. he external gills are prettily branched and tree-like. The two pairs of mbs are yet very small.

FIG. 194.—Larva of the Common Grass-Frog (*Rana temporaria*), a so-lled tadpole: *m*, mouth; *n*, a pair of suction cups used in clinging to stones; skin-fold, which gives rise to the gill-roof; behind are the gill-openings, m which the gill branches protrude; *s*, tail-muscles; *f*, skin-fold of the l, forming a float.

unk is produced into a long tail, which in form and struc-

ture resembles the tail of a Fish (*s*). At first it has no limbs. Respiration is accomplished solely by gills, which are at first external (*k*) and afterwards internal. Correspondingly, the heart is also of the same form as in the Fishes, and consists of only two compartments—an auricle, which receives the venous blood of the body, and a ventricle, which drives it through the arterial bulb into the gills.

Numbers of these fish-like Frog larvæ, or "tadpoles," as they are called, swim about every spring in all ponds and pools, using their muscular tails for propulsion, just as is done by Fishes and larval Ascidians. The remarkable transformation of the fish-like form into that of the Frog does not take place till after the tadpole has grown to a certain size. From the throat grows a closed sac which develops into a pair of large sacs; these are the lungs. The simple chamber of the heart is divided into two auricles, owing to the formation of a partition wall, and simultaneously considerable changes of structure occur in the main arterial trunks. Previously all the blood passed from the heart-chamber through the aorta arches into the gills; but only part of it now passes to the gills, while another part passes through the newly formed lung arteries into the lungs. From the lungs arterial blood returns into the left auricle of the heart, while the venous blood of the body collects in the right auricle. As both of the auricles open into the simple ventricle, the latter contains mixed blood. The fish-like form has now passed into the Dipneusta form. During the further course of modification the gills, with the gill-vessels, are entirely lost, and respiration is now performed by the lungs alone. Yet later, the long tail is also

Fig 1. Siredon pisciformis.

Fig 2. Salamandra maculata.

[redacted]

cted, and the Frog now leaps about on the land on legs ich have sprouted in the mean time.[150]

This remarkable metamorphosis of the higher Amphibia very instructive in its bearing on Man's ancestral history, l is especially interesting owing to the fact that the rious groups of extant Amphibia have remained stationary various stages of their tribal history, which, in accordce with the fundamental law of Biogeny, are reproduced this germ-history. First, there is a very low order of mphibia, the Gilled Batrachians (*Sozobranchia*), which, like ishes, retain their gills throughout life. To this order elong, among others, the well-known blind "Olm" of the delsberg Cave (*Proteus anguineus*), the Mud-eel of South arolina (*Siren lacertina*), and the Axolotl of Mexico (*Siredon pisciformis;* Plate XIII. Fig. 1). All these Gilled atrachians are fish-like animals with long tails, and in oint of respiratory organs and of circulation of the blood hey remain throughout life stationary at the Dipneusta tage. They possess both gills and lungs, and can either espire water through the gills or air through the lungs, as ccasion requires. In another order, the Salamanders, the gills are lost during metamorphosis, and in the adult state air nly is breathed through lungs. This order bears the name f Tailed Batrachians (*Sozura*) because they retain the tail throughout life. To this order belong the common Water-Newts (*Triton*) which swarm in all ponds during the summer, and the black, yellow-speckled Land-Salamanders (*Salamandra*) found in damp woods (Plate XIII. Fig. 2). The latter are among the most remarkable of our indigenous animals, sundry anatomical characters proving them to be very ancient and highly conservative Vertebrates.[151] A

few Tailed Batrachians retain the gill-opening in the si of the neck, though the gills themselves are lost (*Me poma*). If the larvæ of the Salamanders (Fig. 193) a Tritons are compelled to remain in water, and not allow to get on land, they may, under favourable conditions, b made to retain their gills. In this fish-like condition the become sexually mature, and will throughout life remai compulsorily in the lower stage of development of t Gilled Batrachians. The opposite experiment was ma some years ago in the case of the Mexican Gilled Batr chian, the fish-like Axolotl (*Siredon pisciformis;* Pla XIII. Fig. 1). This animal had previously been regard as a permanent Gilled Batrachian, remaining througho life in this fish-like condition. But of the hundreds these animals kept in the Jardin des Plantes at Paris, a fe individuals, for some unknown reason, crept to land, lo their gills, and changed into a form closely allied to that the Salamander (*Amblystoma*, Fig. 2). In this state th became sexually mature.[152] This phenomenon, which first excited a lively interest, has since been repeated observed with care. Zoologists regarded the fact as som thing peculiarly wonderful, though each spring eve common Frog and Salamander passes through the sa modification. In these animals we can in the same w follow each step in the significant metamorphosis of t aquatic and gill-respiring animal into the terrestrial a lung-respiring animal. That which thus takes place in t individual during germ-evolution, took place in the sa way in the whole class during the course of its trib history.

The metamorphosis which takes place in the third ord

mphibia, the Frog Batrachians (*Batrachia*, or *Anura*), more complete than in the Salamanders. To these g all the various kinds of Toads, Water-frogs, Tree- etc. In the course of transformation these lose not the gills, but also the tail, which drops off in some earlier, in others later. In this respect the various s differ somewhat from one another. In most Frog hians the larvæ drop the tail very early, and the s frog-like form subsequently grows considerably . Other species, on the contrary, as, for instance, the es *paradoxus* of Brazil, as also an European Toad (*Pelo-uscus*) remain for a very long time in the fish form, etain a lengthy tail till they have almost attained full size; hence, after their metamorphosis is com- , they appear much smaller than before. The opposite ne is seen in some Frogs but recently brought under , which have lost the whole of their historic meta- oses, and in which no tailed and gilled larva emerges the egg, but the perfect Frog, without tail or gills. Frogs inhabit isolated oceanic islands, the climate ich is very dry, and which are often for a con- ble length of time without fresh water. As fresh is indispensable for gill-respiring tadpoles, these Frogs adapted themselves to this local deficiency and have ly relinquished their original metamorphosis, *e.g.*, es *martinicensis*.[158]

e ontogenetic loss of gills and tail in Frogs and Toads course only be phylogenetically explained as owing fact that these animals have descended from long- salamander-like Amphibians. This is also proved l doubt by the Comparative Anatomy of the two

development of the human embryo; all the many peculiarities in the development of the organs which we shall presently notice in detail; and, finally, the chief special arrangements of the internal structure of the body in all fully developed Amnion Animals; all these so clearly demonstrate the common origin of all Amnion Animals from a single extinct parent-form, that it is impossible to conceive their origin as polyphyletic, and that they originated from several independent parent-forms. This unknown common parent-form is the Primitive Amnion Animal (*Protamnion*). In external appearance the Protamnion was most probably an intermediate form between the Salamanders and the Lizards.

It was probably during the Permian Period that the Protamnion originated; perhaps at the beginning, perhaps at the close of that period. This we know from the fact that the Amphibia did not attain their full development till the Carboniferous Period, and that toward the close of the Permian the first fossil Reptiles make their appearance—or, at least, fossils (*Proterosaurus, Rhopalodon*) which must in all probability be referred to lizard-like Reptiles. Among the great and pregnant modifications of the vertebrate organization determined during this period by the development of the first Amnion Animals from salamander-like Amphibians, the three following are especially important: the total loss of water-breathing gills and modification of the gill-arches into other organs; the formation of the allantois, or primitive urinary sac; and, finally, the development of the amnion.

The total loss of the respiratory gills must be regarded as one of the most prominent characters of all Amnion

Animals. All these, even such as live in the water, *e.g.*, whales, respire only air through lungs, never water through gills. While all Amphibians, with very few exceptions, in the young state retain their gills for a longer or shorter period, and breathe through gills for some time (if not always), from this point gill-respiration entirely ceases. Even the Protamnion must have entirely ceased to breathe water. The gill-arches, however, remain, and develop into very different organs (partly rudimentary); into the various parts of the tongue-bone, into certain portions of the jaw apparatus, the organ of hearing, etc. But no trace of gill-leaves, of real respiratory organs on the gill-arches, are ever found in the embryo of Amnion Animals.

With this total loss of the gills is probably connected the formation of another organ, which we have already described as occurring in human Ontogeny; this is the allantois, or primitive urinary sac. (See vol. i. p. 379.) In all probability the urinary bladder of the Dipneusta is to be regarded as the first beginning of the allantois. Even in the American Mud-fish (*Lepidosiren*) we find an urinary bladder, which grows from the lower wall of the posterior extremity of the intestine, and serves as a receptacle for the renal secretions. This organ has been inherited by the Amphibia, as may be seen in any Frog. But it is only in the three higher Vertebrate classes that the allantois attains a special development; in these it protrudes at an early period from the body of the embryo, forming a large sac filled with liquid, and traversed by a considerable number of large blood-vessels. This sac also discharges a portion of the nutritive functions. In the higher Mammals and in Man the allantois afterwards forms the placenta.

The formation of the amnion and the allantois, together with the total loss of the gills and the exclusive adoption of lung-respiration, are the most important characters by which all Amnion Animals are distinguished from the lower Vertebrates which we have been considering. In addition to these there are a few subordinate characters which are constantly inherited by Amnion Animals, and are altogether wanting in animals without an amnion. One striking embryonic character of the Amnion Animals is the great curvature of the head and neck of the embryo. In the Anamnia the embryo is from the first either nearly straight, or else the whole body is bent in a sickle-shaped curve corresponding to the curvature of the yelk sac, to which the embryo is attached by its ventral surface; but there are no marked angles in the longitudinal axis (Plate VI. Fig. *F*). In all Amnion Animals, on the contrary, the body is very noticeably bent at an early age, so that the back of the embryo is much arched outwards, the head pressed almost at right angles against the breast, and the tail inclined on to the abdomen. The tail extremity, as it bends inwards, approaches so near to the frontal side of the head, that the two often nearly touch (Plates VI. and VII.). This striking triple curvature of the embryonic body, which has already been considered when we studied the Ontogeny of Man, and in which we distinguished the skull-curve, neck-curve, and tail-curve (vol. i. p. 371), is a characteristic peculiarity common to the embryos of all Reptiles, Birds, and Mammals. But in the formation of many internal organs also, an advance is observable in all the Amnion Animals which ranks them above the highest of the non-amnionate forms. Above all, a partition wall forms

in the simple ventricle of the heart, dividing it into a and a left ventricle. In connection with the complete morphosis of the gill-arches, a further development of rgan of hearing takes place. A considerable advance noticeable in the development of the brain, the skele- he muscular system, and other parts. Finally, the struction of the kidneys must be regarded as a most tant modification. In all the lower Vertebrates as yet lered, we have found the primitive kidneys, which r very early in the embryos of all higher Vertebrates Man, acting as a secretory or urinary apparatus. In on Animals, however, these early primitive kidneys heir function at an early period of embryonic life, and ssumed by the permanent "secondary kidneys," which out of the terminal portion of the primitive kidney

ooking back at the whole of these characters of Amnion als, it is impossible to doubt that all animals of this , all Reptiles, Birds, and Mammals, had a common , and constitute a single main division of kindred . To this division belongs our own race. In his organization and germ-history Man is a true Amnion al, and, in common with all other Amniota, has nded from the Protamnion. Although this whole originated at the end, or perhaps even in the middle, e Palæozoic Epoch, it did not attain its full de- ment and its full perfection till the Mesozoic Epoch. wo classes of Birds and Mammals then first appeared. did the Reptilian class develop in its full variety the Mesozoic Epoch, which is, therefore, called the "Age ptiles." The unknown and extinct Protamnion, the

parent-form of the entire group, must have been very n allied to the Reptiles in its whole organization, even th it cannot be regarded as a true Reptile in the pr meaning of the term. Of all known Reptiles, certain Li are most nearly allied to the Protamnion; and in outward form of its body we may imagine the latt an intermediate form between the Salamander and Lizard.[156]

The Comparative Anatomy and Ontogeny of the nionate group clearly explains its genealogy. The which directly descended from Protamnion gave rise t divergent branches. The first of these, which will in f receive our whole attention, forms the Mammalian g The other branch, which assumed an entirely different c of progressive development, and which is connected the mammalian branch only as the root, is the co hensive group constituted by Reptiles and Birds. Th latter forms may be classed together as *Monocondyl Sauropsides.* The common parent-form of these extinct lizard-like Reptile. From this, the Serpents, C diles, Tortoises, Dragons, etc.—in short, all the various of the Reptilian group—developed in different direc The remarkable group formed by the Birds also deve directly from an offshoot of the Reptilian group, as is definitely proved. Down to a late time the embry Reptiles and of Birds are yet identical, and even later are in some respects surprisingly similar. (See Plate VI *T* and *C.*) In their entire organization the resemb between the two is so great that no anatomist now d that the Birds originated from Reptiles. The Mamm line is connected at its roots with the Reptilian line

rds diverged entirely from the latter, and developed
ntirely peculiar direction. The highest result of the
ment of the Mammalian line is Man, the so-called
n of Creation."

CHAPTER XIX.

THE PEDIGREE OF MAN.

IV. From the Primitive Mammal to the Ape.

The Mammalian Character of Man.—Common Descent of all Mammals from a Single Parent-form (Promammalian).—Bifurcation of the Amnion Animals into Two Main Lines: on the one side, Reptiles and Birds, on the other, Mammals.—Date of the Origin of Mammals: the Trias Period.—The Three Main Groups or Sub-classes of Mammals: their Genealogical Relations.—Sixteenth Ancestral Stage: Cloacal Animals (*Monotremata*, or *Ornithodelphia*).—The Extinct Primitive Mammals (*Promammalia*) and the Extant Beaked Animals (*Ornithostoma*).—Seventeenth Ancestral Stage: Pouched Animals (*Marsupialia*, or *Didelphia*).—Extinct and Extant Pouched Animals.—Their Intermediate Position between Monotremes and Placental Animals.—Origin and Structure of Placental Animals (*Placentalia*, or *Monodelphia*).—Formation of the Placenta.—The Deciduous Embryonic Membrane (*Decidua*).—Group of the *Indecidua* and of the *Deciduata*.—The Formation of the Decidua (*vera, serotina, reflexa*) in Man and in Apes.—Eighteenth Stage: Semi-apes (*Prosimiæ*).—Nineteenth Stage: Tailed Apes (*Menocerca*).—Twentieth Stage: Man-like Apes (*Anthropoides*).—Speechless and Speaking Men (*Mali. Homines*).

"A century of anatomical research brings us back to the conclusion of Linnæus, the great lawgiver of systematic zoology, that man is a member of the same order as the apes and lemurs. Perhaps no order of mammals presents us with so extraordinary a series of gradations as this, leading us insensibly from the crown and summit of the animal creation down to creatures from which there is but a step, as it seems, to the lowest, smallest, and least intelligent of the placental mammalia. It is as if nature herself

had foreseen the arrogance of man, and with Roman severity had that his intellect, by its very triumphs, should call into promi selves, admonishing the conqueror that he is but dust."—THOMAS (1863).

AMONG those zoological facts which afford us points of support in researches into the pedigree of the human race, the position of Man in the Mammalian class is one of the most important and fundamental. Much as zoologists have long disagreed in their opinions as to Man's particular place in this class, and especially in their ideas of his relation to the most nearly related group, that of the Apes, yet no naturalist has ever doubted that Man is a genuine Mammal in the whole structure and development of his body. Every anatomical museum, every manual of Comparative Anatomy, affords proof that the structure of the human body shares all those peculiarities which are common to all Mammals, and by which the latter are definitely distinguished from all other animals.

Now, if we examine this established anatomical fact phylogenetically, and in the light of the Theory of Descent, we arrive immediately at the conclusion that Man is of a common stock with all the other Mammals, and springs from a root common to them. The various characteristics in which all Mammals coincide, and in which they differ from all other animals, are, moreover, of such a kind, that a polyphyletic hypothesis appears in a special degree inadmissible in their case. It is inconceivable that all existing and extinct Mammals have sprung from several different and originally separate root-forms. We are compelled, if we in any way acknowledge the Theory of Evolution, to assume the monophyletic hypothesis, that all Mammals,

including Man, must be traced from a single common mammalian parent-form. This long extinct primæval root-form and its immediate descendants—which differ from each other hardly more than do several species of one genus—we will call Primitive Mammals (*Promammalia*). As we have already seen, this root-form developed from the ancient parent-form of the Primitive Amnion Animals in a direction wholly different from that followed by the Reptile group, which afterwards gave rise to the more highly developed class of Birds. The differences which distinguish Mammals on the one side, from Reptiles and Birds on the other, are so important and characteristic, that we may quite safely assume a bifurcation of this kind in the vertebrate family tree. Reptiles and Birds—which we classed together as *Monocondylia*, or *Sauropsida*—coincide entirely, for instance, in the characteristic structure of the skull and brain, which is strikingly dissimilar from that of the same parts in Mammals. In Reptiles and Birds, the skull is connected with the first cervical vertebra (the atlas) by a single joint-process (condyle) of the occipital bone; in Mammals, on the contrary (as in Amphibians), the condyle is double. In the former, the under jaw is composed of many parts, and is connected with the skull by a peculiar bone of the jaw (the square bone) so as to be movable; in the latter, on the contrary, the lower jaw consists of but two bone-pieces, which are directly attached to the temporal bone. Again, the skin of the Sauropsida (Reptiles and Birds) is covered with scales or feathers, that of the Mammals with hair. The red blood-cells of the former are nucleated, those of the latter non-nucleated. The eggs of the former are very large, are provided with a large nutritive yelk, and underg

discoidal cleavage resulting in a Disc-gastrula; the eggs of the latter are very small, and their unequal cleavage results in the formation of a Hood-gastrula. Finally, two characters entirely peculiar to Mammals, and by which these are distinguished both from Birds and Reptiles and from all other animals, are the presence of a complete diaphragm, and of the milk-glands (*mammæ*), by means of which the new-born young are nourished by the milk of the mother. It is only in Mammals that the diaphragm forms a transverse partition-wall across the body-cavity (*cœloma*), completely separating the chest from the ventral cavity. (Cf. Plate V. Fig. 16 *z*.) It is only among Mammals that the mother nourishes the young with her milk; and the whole class are well named from this.

These important facts in Comparative Anatomy and Ontogeny clearly show that the tribe of Amnion Animals (*Amniota*) bifurcated from the very first into two main diverging lines; on the one side, the Reptilian line, from which the Birds afterwards developed; on the other side, the Mammalian line. The same facts also prove as indubitably that Man originated from the latter line. For Man, in common with Mammals, shares all the characteristics we have mentioned, and is distinguished by them from all other animals. And, finally, these facts indicate as certainly those advances in vertebrate structure by which one branch of the Primitive Amnion Animals developed into the parent-form of Mammals. The most prominent of these advances were (1) the characteristic modification of the skull and brain; (2) the formation of a covering of hair; (3) the complete development of the diaphragm; and (4) the formation of the milk-glands and the adaptation to the suckling of

the young. Intimately connected with these, other portant structural modifications gradually occurred.

The period at which these important advances, wl laid the first foundation of the Mammalian class, took pl may most probably be placed in the first part of Mesolithic, or Secondary Epoch, in the Triassic Pei For the oldest known fossil remains of Mammals occu sedimentary rock-strata of the most recent deposits of Triassic Period, in the upper Keuper. It is possi indeed, that the parent-forms of Mammals may h appeared earlier (perhaps even at the close of the Pal lithic Epoch, in the Permian Period). But no fossil rem of Mammals belonging to that period are as yet kno Throughout the Mesolithic Epoch, throughout the Tria Jurassic, and Calcareous Periods, fossil remains of Mamn are very scarce, and indicate a very limited developm of the whole class. During this Mesolithic Epoch, Rept play the chief part, and Mammals are of quite second importance. It is, however, especially significant interesting, that all mammalian fossil remains of Mesozoic Epoch belong to the older and inferior divi of Pouched Animals (*Marsupialia*), a few probably e to the yet older division of the Cloacal Animals (*M trema*). Among them, no traces of the third and n highly developed division of the Mammals, the Place Animals, have as yet been found. The last, to which l belongs, are much more recent, and their fossil remain not occur till much later—in the succeeding Cænoli Epoch; in the Tertiary Period. This palæontological is very significant, because it harmonizes perfectly that order of the development of Mammals which is

istakably indicated by Comparative Anatomy and Onto-
ny.

These show that the whole Mammalian class is divisible
o three main groups, or sub-classes, corresponding to
ree successive stages of phylogenetic evolution. These
ree stages, which consequently represent three important
estral stages in the human pedigree, were first dis-
guished in the year 1816 by the celebrated French
logist, Blainville, who named them, according to the
ferent structure of the female organs of reproduction,
nithodelphia, *Didelphia*, and *Monodelphia* (δελφύς,
ich, being interpreted, is *uterus*). It is not, however,
y in the varied structure of the sexual organs that these
ee classes differ from one another, but in many other
pects also, so that we can safely maintain the important
ylogenetic statement: The *Monodelphia*, or Placental
imals, have descended from the *Didelphia*, or Pouched
imals; and the latter, again, have descended from the
acal Animals, or *Ornithodelphia*.

Accordingly we have now to consider, as the sixteenth
estral stage in the human pedigree, the oldest and lowest
in group of Mammals; the sub-class of the Cloacal
imals (*Monotremata*, or *Ornithodelphia*). They are so
ned in consequence of the cloaca, which they have in
mon with the other lower Vertebrates. This so-called
ca is the common excretory channel for the excrement,
urine, and the sexual products (Fig. 327). For, in
se Cloacal Animals, the urinary duct and the sexual
als yet open into the posterior parts of the intestine,
le in all other Mammals they are wholly separated from
rectum and anus, and open by a special orifice (*porus*

urogenitalis). The urinary bladder in the Monotremes als opens into the cloaca, and is separate from the two urinar ducts (Fig. 327, *vo*); in all other Mammals the latter ope directly into the urinary bladder. The structure of th milk-glands, by means of which all Mammals suckle thei new-born young for a time, is also quite peculiar i the Cloacal Animals. In them the milk-gland has n nipple which the young animal can suck; there is onl a peculiar sieve-like place in the skin, perforated wit holes through which the milk passes out, and from which the young animal has to lick it. For this reason they have also been called Nipple-less Mammals (*Amasta*). Again, the brain of the Cloacal Animals has remained at a much lower stage of development than that of any other Mammal. The fore-brain, or cerebrum, is so small that it does not overhang the hind-brain, or cerebellum. In the skeleton (Fig. 196), the structure of the shoulder girdle, as well as of other parts, is remarkable, differing entirely from the same part in other Mammals, and resembling rather those of the lower Vertebrates, especially Reptiles and Amphibians. Like the latter, the Cloacal Animals have a well-developed coracoid bone (*coracoideum*), a strong bone uniting the shoulder-blade with the breast-bone. In all other Mammals the coracoid bone (as in Man) has degenerated, has coalesced with the shoulder-blade, and appear only as an insignificant process of the latter. These and many other less striking peculiarities prove beyond doub that the Cloacal Animals occupy the lowest rank amon Mammals, and represent a direct intermediate form betwee the Protamnia and other Mammals. All these marked Am phibian characters must have been present in the paren

n of the whole vertebrate class, in the Primitive nmal, by which they must have been inherited from Primitive Amnion Animals.

During the Triassic and Jurassic Periods, the sub-class he Cloacal Animals seems to have been represented by ny Primitive Mammals of very varied form. At present s represented only by two isolated members, which grouped together as the Beaked Animal family (*Ornitoma*). Both of these are confined to Australia and the ghbouring island of Van Diemen's Land, or Tasmania; h are becoming less numerous year by year, and will n be classed, with all their blood relations, among the inct animals of our globe. One of these forms passes life swimming about in rivers, and builds subterranean ellings on the banks: this is the well-known Duck-ed Platypus (*Ornithorhynchus paradoxus*): it is web-ted, has a thick, soft skin, and broad, flat jaws, which y much resemble a duck's bill (Figs. 195, 196). The er form, the Porcupine Ant-eater (*Echidna hystrix*), much embles the Ant-eaters, in its mode of life, in the cha-teristic form of its slender snout, and in the great length its tongue; it is covered with prickles, and can roll itself into a ball like a hedgehog. Neither of these extant aked Animals possesses true bony teeth, and, in this nt, they resemble the Toothless Mammals (*Edentata*). e absence of teeth, together with other peculiarities of Ornithostomata, is probably the result of comparatively ent adaptation. Those extinct Cloacal Animals which braced the parent-forms of the whole Mammalian class, Promammalia, must certainly have been provided with leveloped set of teeth, inherited from Fishes.[157] Some

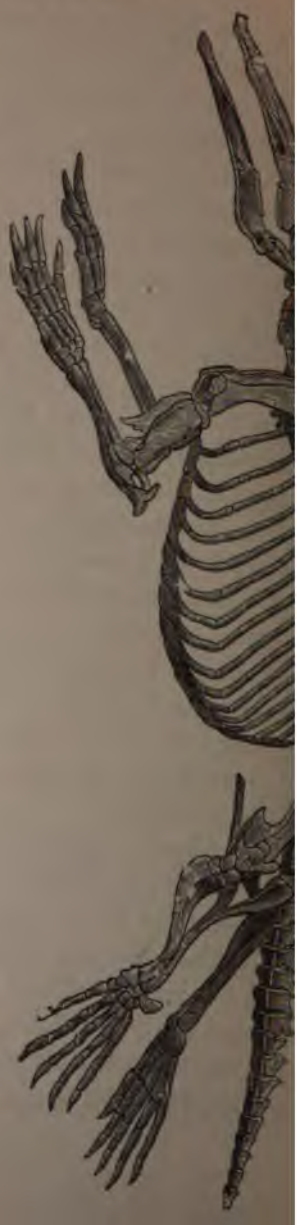


FIG. 195.—The Duck-billed Platypus (*Ornithorhynchus paradoxus*).
FIG. 196.—Skeleton of Platypus.

ll single molars, found in the uppermost strata of Keuper formation in England and Würtemberg, and ch are the oldest known vertebrate remains, probably ng to these primæval Promammalia. These teeth, by r form, indicate species that lived on insects; the species been called *Microlestes antiquus*. Teeth belonging to her closely allied Primitive Mammal (*Dromatherium stre*) have recently been discovered in the North rican Trias.

On the one hand, the still extant Beaked Animals, and, on other, the parent-forms of the Pouched Animals (*Marialia*, or *Didelphia*), must be regarded as representing distinct and divergent lines of descent from the Promalia. This second Mammalian sub-class is very resting as a perfect link between the two other sub-es. While the Pouched Animals, on the one side, retain y of the characters of the Cloacal Animals, they also, the other, possess many placental characters. A few acters are quite peculiar to Pouched Animals alone; , for instance, is the structure of the male and female al organs, and the form of the lower jaw. The distive feature of the latter in these Pouched Animals is a liar hook-shaped bony process, passing inward horially from the angle of the lower jaw. As neither cal Animals nor Placental Animals have this process, structure is alone sufficient to distinguish the Pouched mals (*Marsupialia*). Nearly all the known mammalian ls from the Jurassic and Cretaceous formation are lower . Our whole knowledge of numerous mesolithic mam-a, the former existence of which would otherwise never been known, is solely derived from their fossilized

lower jaws, no fragment of the rest of their bodies having been reserved. According to the logic usually applied to palæontology by the "exact" opponents of the theory of evolution, the inference drawn from this fact would be that these Mammals had no bones except lower jaws. The remarkable circumstance is, after all, very easily accounted for. The lower jaw of Mammals being a solid and exceptionally hard bone, but very loosely attached to the skull, it is easily detached from the carcase as the latter is carried down by some river, and, falling to the bottom, is retained in the mud. The rest of the carcase is carried on further, and is gradually destroyed. As all the mammalian lower jaws found, in England, in the Jurassic strata of Stonesfield and Purbeck, exhibit this peculiar process characteristic of the Pouched Animals (*Marsupialia*), we may infer, from this palæontological fact, that they belonged to Marsupials. No Placental Animals appear to have existed during the Mesolithic Epoch. At least no fossil remains, undoubtedly belonging to these and dating from that epoch, are known.

The extant Pouched Animals, the most generally known of which are the gramnivorous Kangaroos and the carnivorous Pouched Rats, display very considerable difference in their organization, in the form of their bodies and in size, and in many respects correspond to the several orders of Placental Animals. The great majority of them live in Australia, in New Holland, and in a few of the Australian and South Asiatic islands; some few species occur in America. On the other hand, there is no longer a single indigenous Pouched Animal on the continents of Asia, of Africa, or of Europe. The case was very different during the Mesolithic, and also during the earlier Cænolithic Epochs

The Neptunian deposits of these epochs in all quarters of the globe, and even in Europe, contain abundant marsupial remains in great variety, some of them being of very large size. From this we may infer that the extant Pouched Animals are but the last remnant of a group which was once much more widely developed, and which was distributed over the whole surface of the globe. During the Tertiary Period, these succumbed in the struggle for life with the stronger Placental Animals, and the survivors were gradually driven back by the latter into their present restricted area.

From the Comparative Anatomy of the extant Pouched Animals, very important conclusions may be drawn as to their phylogenetic intermediate position between Cloacal Animals and Placental Animals. The incomplete development of the brain, especially of the fore-brain (*cerebrum*), the possession of marsupial bones (*ossa marsupialia*), the simple structure of the allantois (which does not as yet develop a placenta), with many other characters, have been inherited by the Pouched Animals from Cloacal Animals. On the other hand, they have lost the independent coracoid bone (*os coracoideum*) attached to the shoulder girdle. A more important step consists in the fact that a cloaca is no longer formed; the cavity of the rectum, together with the anal opening, is separated by a partition wall from the urinary and sexual opening (*sinus urogenitalis*). Moreover, all Pouched Animals develop special nipples on the milk-glands, which are sucked by the young after birth. These nipples project into the cavity of a pouch, or marsupium, in the ventral side of the mother. This pouch is supported by a couple of marsupial bones. In it the young, which are

born in a very imperfect condition, are carried by the mother for a long time; until, in fact, they are completely developed (Fig. 197). In the large Giant Kangaroo, which

FIG. 197.—The Crab-eating Pouched Rat (*Philander cancrivorus*). A *female* with two young in its pouch. (After Brehm.)

ttains the height of a man, the embryo develops in the terus but for a month; it is then born in a very incomplete ondition, and attains all its further development in the nother's pouch, where, for about nine months, it remains ttached to the milk-glands.

All these and other characters (especially the peculiar tructure of the internal and external sexual organs of the nale and female) clearly show that the whole sub-class of he Pouched Animals (*Marsupialia*) are a single group, which originated from the promammalian branch. From a branch of these Pouched Animals (perhaps from several branches) the parent-forms of the higher Mammals, the Placental Animals, afterwards sprang. Hence we must reckon a whole series of Pouched Animals among the ancestors of the human race; and these constitute the seventeenth stage in the human pedigree.[158]

The remaining stages of our ancestral line, from the eighteenth to the twenty-second, all belong to the group of Placental Animals (*Placentalia*). This very highly developed group of Mammals, the third and last, came into the world at a considerably later period. No single known fossil, belonging to any portion of the Secondary or Mesolithic Epoch, can be referred with certainty to a Placental Animal, while we have plenty of placental fossils dating from every part of the Tertiary or Cænolithic Epoch. From this palæontological fact we may provisionally infer that the third and last main division of Mammals did not develop from the Pouched Animals until the beginning of the Cænolithic Epoch, or, at the earliest, till the close of the Mesolithic Epoch (during the Chalk Period). In our survey of geological formations and periods (pp. 12, 19) we found

how comparatively short this whole Tertiary or Cænol Epoch was. Judging from the relative thicknesses of various strata-formations we were able to say that whole period, during which Placental Animals first appe and assumed their respective forms, amounted at mos about three per cent. of the entire duration of the org history of the earth. (Cf. p. 18.)

All Placental Animals are distinguished from the lower Mammalian groups already considered, from Cloacal Animals and Pouched Animals, by many promi peculiarities. All these characters are present in Ma most significant fact. For on the most accurate compar anatomical and ontogenetical researches, we may bas irrefutable proposition that Man is in every respect a Placental Animal; in him are present all those peculia in the structure and in the development of the body w distinguish Placental Animals from the lower Mamm groups, and at the same time from all other ani Among these characteristic peculiarities the higher dev ment of the brain, the organ of the mind, is espec prominent. The fore-brain, or large brain (*cerebrun* much more highly developed in these than in l animals. The body (*corpus callosum*), which, like a br connects the two hemispheres of the fore-brain, attain full development only in Placental Animals; in the Pou Animals and Cloacal Animals it exists merely as an ins ficant rudiment. It is true that in their brain stru the lowest of the Placental Animals yet resemble Pou Animals very nearly; but within the Placental grou can trace a continuous series of progressive stages in *development* of the brain, ascending quite gradually

ie lowest stage to the very highly developed mind-organ f the Monkey and of Man. (Cf. Chapter XX.) The uman mind is but a more highly developed ape-mind.

The milk-glands of Placental Animals, as of Marsuials, are provided with developed nipples; but the pouch which the immature young of the latter are carried bout and suckled is never present in the former. Nor are he marsupial bones (*ossa marsupialia*) present in Placental Animals; these bones, which are embedded in the bdominal wall, and rest on the anterior edge of the pelvis, re common to Pouched Animals and Cloacal Animals, oriinating from a partial ossification of the tendons of the nner oblique muscle of the abdomen. It is only in a few easts of prey that insignificant rudiments of these bones are ound. The hook-shaped process of the lower jaw, which haracterizes Pouched Animals, is also entirely wanting in Placental Animals.

The character, however, which especially distinguishes Placental Animals, and which has justly given its name to the entire sub-class, is the development of the placenta, or vascular cake. We have already spoken of this organ, in escribing the development of the allantois in the human mbryo (vol. i. p. 382). The urinary sac or allantois, that eculiar bladder which grows out of the posterior portion of he intestinal canal, is, we found, formed at an early stage in ie human embryo just as in the germs of all other Amnion nimals. (Cf. Figs. 132–135, vol. i. p. 377–380.) The thin wall f this sac consists of the same two layers, or skins, as the all of the intestine itself; internally of the intestinal-glanular layer, and externally of the intestinal-fibrous layer. he cavity of the allantois is filled with fluid; this primi-

tive urine must be chiefly the product of the primitiv kidneys. The intestinal fibrous layer of the allantois i traversed by large blood-vessels which accomplish the nutri ment and, especially, the respiration of the embryo; thes are the navel-vessels, or umbilical vessels (vol. i. p. 400). I all Reptiles and Birds the allantois becomes an immens sac, which encloses the embryo with the amnion, and whic does not coalesce with the outer covering of the eg (*chorion*). In Cloacal Animals (*Monotremata*) and Pouche Animals (*Marsupialia*) the allantois is also of this nature It is only in Placental Animals that the allantois develop into that very peculiar and remarkable formation, calle the *placenta*, or "vascular cake." The nature of the placent is this: the branches of the blood-vessels which traverse th wall of the allantois, penetrate into the hollow tufts of th chorion, which are inserted into corresponding depression in the mucous membrane of the maternal uterus. As thi mucous membrane is also abundantly supplied with blood vessels, which conduct the mother's blood into the uterus and as the partition between these maternal blood-vessel and the embryonic vessels in the chorion-tufts soon become extremely thin, a direct exchange of substance is soon de veloped between the two sets of blood-vessels, which is c the utmost importance for the nutrition of the youn Mammal. The maternal blood-vessels do not, howeve pass directly (anastomosis) into the blood-vessels of th embryonic chorion-tufts, so that the two kinds of bloo simply mix, but the partition between the two sets vessels becomes so thin, that it permits the passage of th most important food-materials, freed from unnecessar matter (transudation, or diosmosis). The larger the embry

rows in Placental Animals, and the longer it remains in e maternal uterus, the more necessary does it become that pecial structural arrangements should meet the increased nsumption of food. In this point there is a very striking ifference between the lower and the higher Mammals. In loacal Animals and Pouched Animals, in which the embryo emains for a comparatively brief time in the uterus, and is orn in a very immature condition, the circulation as it exists n the yelk-sac and in the allantois suffices for nutrition, as n birds and reptiles. In Placental Animals, on the contrary, n which gestation is very protracted, and the embryo emains much longer in the uterus, there attaining its full levelopment within its investing membranes, a new apparatus is required to convey a direct supply of richer nutritive matter; and this is admirably effected by the development of the placenta.

In order rightly to understand and appreciate the formation of this placenta and its important modifications in different Placental Animals, we must once more glance at the external coverings of the mammalian egg. The outermost of these was originally, and during the cleavage of the egg and the first formation of the axial portion of the germ, formed by the so-called *zona pellucida*, and by the thick albuminous covering deposited externally on the latter (Fig. 19, Fig. 21, *z*, *h*, vol. i. p. 178).

We called these two outer coverings, which afterwards amalgamate, the *prochorion*. This prochorion very soon disappears (in man perhaps in the second week of development), and is replaced by the permanent outer egg-membrane, the chorion. The latter, however, is simply the serous membrane, which, as we have already seen, is the

product of the outer germ-layer of the germ-men
vesicle. (See vol. i. p. 401, and Fig. 139, $_4$, $_5$, *sh*, p. 385.)
is at first a very smooth, thin membrane, surroundi
entire egg, as a closed spherical vesicle, and consistin
single layer of exoderm cells. The chorion, howev
comes very soon studded with a number of little pr
ances or tufts (Fig. 139, $_5$, *chz*). These fit themselv
indentations in the mucous membrane of the uteru
thus secure the egg to the wall of the latter. Th
are, however, not solid, but hollow, like the finge
glove. Like the whole chorion, these hollow tufts co
a thin layer of cells belonging to the horn-plate.
very soon attain an extraordinary development, g
and branching rapidly. In the spaces between the

FIG. 198.—Egg-cov
the human embryo (
matic): *m*, the thick fl
of the uterus; *plu*,
the inner stratum
which has extended
between the chorion-t
(*chf*, tufted, *chl*, sm
rion); *a*, amnion; *a*
cavity; *as*, amnion s
the navel-cord (passi
into the navel of the
which is not represent
dg, yelk-duct; *ds*,
dv, *dr*, decidua (*dv*,
false). The uterus-ca
opens below into th
above, on the right h
into an oviduct (*t*).
Kölliker.)

tufts arise in all directions from the serous membra
thus before long (in the human embryo in the third

the whole outer surface of the egg is covered with a dense forest of tufts (Fig. 134).

These hollow tufts are now penetrated from within by the branching blood-vessels, which originate from the intestinal fibrous layer of the allantois, and which contain the blood of the embryo, introduced through the navel vessels (Fig. 198, *chz*). On the other hand, dense networks of blood-vessels develop in the mucous membrane, which lines the inner surface of the uterus, particularly in the neighbourhood of the depressions into which the chorion-tufts penetrate (*plu*). These vascular networks receive the blood of the mother introduced through the uterus vessels. The whole mass of these two sets of vessels, which are here most intimately connected, together with the connecting and enveloping tissues, is called the placenta, or "vascular cake." Properly speaking, the placenta consists of two quite different, though closely connected, parts; internally, of the embryonic placenta (*placenta fœtalis*, Fig. 198, *chz*), and externally of the maternal placenta (*placenta uterina*, Fig. 198, *plu*). The latter is formed by the uterine mucous membrane and its blood vessels: the former by the secondary chorion and the navel vessels of the embryo.

The mode in which these two "vascular cakes" combine to form the placenta, as well as the structure, form, and size of the latter, differs much in different Placental Animals, and affords valuable data for natural classification, and hence also for the tribal history of the whole sub-class. The latter is primarily divisible into two main divisions, based on these differences: the lower Placental Animals, which are called *Indecidua*, and the higher Placental Animals, or *Deciduata*.

To the Indecidua, or lower Placental Animals, be two very comprehensive and important vertebrate gro (1) the Hoofed Animals (*Ungulata*)—the Tapirs, H Swine, Ruminants, and others; (2) the Whale-like ani (*Cetomorpha*)—the Sea-cows, Porpoises, Dolphins, Wl and others. In all these Indecidua the chorion tuft distributed, singly or in bunches, over the entire surfa the chorion, or over the greater part of it. They are but loosely attached to the mucous membrane of the uter that the entire outer egg-membrane with its tufts n easily and without using force be drawn out of the depres in the uterine mucous membrane, just as the hand is drawn from a glove. The two "vascular cakes" d really coalesce at any point of their contact. Henc birth the "embryonic cake" (*placenta fœtalis*) is removed; the "maternal cake" (*placenta uterina*) i displaced. The entire mucous membrane of the g uterus is but little altered, and, at parturition, suffe direct loss of substance.

The structure of the placenta in the second and h division of Placental Animals, the Deciduata, is very ferent. To this comprehensive and very highly devel mammalian group belong all Beasts of Prey and all In eaters, Gnawers (*Rodentia*), Elephants, Bats, Semi-apes, lastly, Apes and Man. In all these Deciduata the surface of the chorion is also at first thickly covered tufts. These, however, afterwards disappear from pa the surface, while they develop all the more vigorous the remainder. The smooth chorion (*chorion lævе*, Fig. *chl*) thus becomes distinct from the tufted chorion (*ch frondosum*, Fig. 198, *chf*). On the former there are

minute and scattered tufts, or none at all; while the latter is thickly overgrown with highly developed and large tufts. In the Deciduata the tufted chorion alone forms the placenta.

Yet more characteristic of the Deciduata is the very peculiar and intimate connection which is developed in these between the tufted chorion and the contiguous portion of the uterine mucous membrane, and which must be regarded as a true coalescence. The vascular tufts of the chorion push their branches into the sanguineous tissue of this mucous membrane in such a way, and the two sets of vessels are in such close contact and are so interlaced, that the embryonic placenta is no longer distinguishable from the maternal placenta; the two form one whole—a compact and apparently simple placenta. Owing to this intimate coalescence, a portion of the uterine mucous membrane of the mother comes away, at birth, with the firmly adherent egg-membrane. The portion of the mother's body which is thus removed in parturition is called, on account of its separable nature, the deciduous membrane (*decidua*). All Placental Animals which possess this deciduous membrane are classed together as Deciduata. The removal of this membrane at parturition, of course, causes a greater or less loss of blood by the mother, which does not occur in the Indecidua. In the Deciduata, moreover, the lost portion of the uterine mucous membrane must be replaced, after parturition, by a renewal of the tissue.

The structure of the placenta and deciduous membrane is, however, by no means identical throughout the comprehensive group of Deciduata. On the contrary, there are many important differences in this respect, which are in

some degree connected with other important structural characters (*e.g.*, the structure of the brain, of the teeth, of the feet), and which may justly, therefore, be turned to account in the phylogenetic classification of Placentals. In the first place, two great groups of Deciduata may be distinguished according to the form of the placenta: in the one group it is ring-shaped or girdle-shaped; in the other it is discoid or cake-shaped. In Deciduata with girdle-shaped placenta (*Zonoplacentalia*) the poles of the oval egg take no part in the formation of the placenta. The "vascular cake" resembles a broad ring-like girdle, embracing the central zone of the egg. It is so in Beasts of Prey (*Carnassia*), both in the terrestrial forms (*Carnivora*) and in the marine forms (*Pinnipedia*). A similar girdle-shaped placenta is found in the False-hoofed Animals (*Chelophora*): the elephants, and Klip Das (Hyrax) with its allies, which were formerly classed as Hoofed Animals. All these Zonoplacentalia belong to one or more side-branches of the Deciduata which are not nearly allied to Man.

The second and most highly developed group is formed by the Deciduata with discoidal placenta (*Discoplacentalia*). The formation of the placenta is here most localized and its structure most fully developed. The placenta forms a thick, spongy cake, usually in the form of a circular or oval disc, and attached only to one side of the uterine wall. The greater part of the embryonic egg-membrane is, therefore, smooth, without developed tufts. To the Discoplacentalia belong the Semi-apes and Insect-eaters, the Diggers (Effodienta) and the Sloths, Rodents and Bats, Apes and Man. Comparative Anatomy enables us to infer that of these various orders the Semi-apes are the parent-

group from which all other Discoplacentals, and perhaps even all Deciduous Animals, have developed as divergent branches. (Cf. Tables XXIII. and XXIV.)

The Semi-apes (*Prosimiæ*) are now represented only by very few forms. These, however, are very interesting, and must be regarded as the last remnants of a group once rich in forms. This group is certainly very ancient, and was probably very prominent during the Eocene Epoch. Their present degraded descendants are scattered widely over the southern portion of the Old World. Most of the species inhabit Madagascar; a few the Sunda Islands; a few others the continents of Asia and Africa. No living or fossil Semi-apes have, as yet, been found in Europe, America, or Australia.[159] The widely scattered posterity of the Semi-apes is considerably diversified. Some forms seem nearly allied to the Marsupials, especially to the Pouched-rats. Others (*Macrotarsi*) are very near akin to the Insect-eaters, and yet others (*Cheiromys*) to the Gnawers (*Rodentia*). One genus (*Galeopithecus*) forms a direct transition to the Bats. Finally, some of the Semi-apes (*Brachytarsi*) approach very near to true Apes. Among the latter are some tail-less forms (*e.g.*, the Lori, *Stenops*, Fig. 199). From these highly interesting and important relations of the Semi-apes to the various Discoplacental orders, we may fairly infer that of the extant representatives of this group, they are the nearest to the common primitive parent-form. Among the direct common ancestors of Apes and Men, there must have been some Deciduata which we should class among the Semi-apes, were we to see them alive. We may therefore consider this order as a special stage, following the Pouched Animals, as the eighteenth stage in the human pedigree

Probably our ancestors among the Semi-apes closely r
sembled the extant Brachytarsi or Lemurs (*Lemur, Licha*

FIG. 199.—The Slender Lori of Ceylon (*Stenops gracilis*).

otus, Stenops), and, like these, led a quiet life, climbing
trees. The extant Semi-apes are mostly nocturnal anir
of gentle and melancholy disposition, subsisting on fruit

Semi-apes are immediately followed by the true
imiæ), as the nineteenth stage in the human pedi-
t has long been beyond doubt that of all animals
s are in all respects the most nearly allied to Man.
on the one side, the lowest Apes approach very near
Semi-apes, so, on the other side, do the highest Apes
osely resemble Man. By carefully studying the Com-
e Anatomy of Apes and Man, it is possible to trace a
uninterrupted advance in the Ape-organization up to
ely human structure; and on impartially testing this
uestion," which has lately been agitated with such
ate interest, we shall infallibly have to acknowledge
ortant fact, which was first explicitly laid down by
that "whatever system of organs be studied, the
son of their modifications in the ape series leads to
l the same result—that the structural differences
eparate Man from the Gorilla and Chimpanzee are
great as those which separate the Gorilla from the
pes." In phylogenetic language this pregnant law
ed in so masterly a manner by Huxley, is equiva-
he popular phrase: Man is descended from the Ape.
rder to become convinced of the truth of this law,
ow once more consider the placenta and deciduous
ne, on the varied structure of which we justly laid
tress. Men and Apes, in the structure of their disc-
placenta and in their decidua, do, indeed, coincide
whole with all other Discoplacental Animals. But
more delicate structure of these parts Man is dis-
ed by peculiarities which he shares only with Apes,
ich are absent in other Deciduata. Thus in Man
the Apes three distinct parts are recognized in the

deciduous membrane; these parts may be called the out the inner, and the placental deciduous membrane. T outer or true membrane (*d. externa* or *vera*, Fig. 198, Fig. 200, *g*), is that portion of the uterine mucous membra which coats the internal surface of the uterus wherever

FIG. 200.—Human embryo, twelve weeks old, with its coverings; n size. The navel cord passes from the navel to the placenta: *b*, an *c*, chorion; *d*, placenta; *d'*, remains of tufts on the smooth chorion; *cidua reflexa* (inner); *g*, *decidua vera* (outer). (After Bernhard Schu

latter is not attached to the placenta. The placent spongy deciduous membrane (*d. placentalis* or *sero* Fig. 198, *plu*, Fig. 200, *d*) is simply the maternal pla

lf, or the maternal part of the "vascular cake" (*pla-ta uterina*), *i.e.*, that part of the uterine mucous mem-ne which coalesces intimately with the chorion-tufts of

o. 201.—Mature human embryo (at the end of pregnancy), in its natural on, taken out of the uterus. On the inner surface of the latter (on ft) is the placenta, which is attached to the navel of the child by the cord. (After Bernhard Schultze.)

embryonic placenta (*placenta fœtalis*). Lastly, the r or false deciduous membrane (*d. interna* or *reflexa*, 198, *dr*, Fig. 200, *f*) is that portion of the uterine mucous brane which, as a peculiar thin envelope, covers all the of the egg-surface, lying immediately over the tuftless th chorion (*chorion lævе*). The origin of these three act deciduous membranes, concerning which erroneous ns have been entertained (still retained in the nomen-re), is plain enough; the external or true deciduous

membrane is a peculiar modification, afterwards lost, of t superficial layer of the original mucous membrane of t uterus. The placental membrane is that portion of t preceding which is completely modified by the intrusion the chorion-tufts and is employed in forming the placen Lastly, the inner deciduous membrane is formed by ring-shaped fold of the mucous membrane (at the po of union of the *d. vera* and the *d. serotina*) which ri grows round the egg, and closes in the same way as amnion.[160]

The peculiar anatomical characters which mark the hun egg-membrane re-occur, in the same form, only in Apes. other Discoplacental Animals present greater or less dif ences in these points, the conditions being generally m simple. This is the case, for instance, in the structure the placenta itself, in the coalescence of the chorion-tı with the *decidua serotina*. The matured human place is a circular (rarely oval) disc of a soft, spongy charac 6 to 8 inches in diameter, about 1 inch thick, and weigh from 1 to 1½ lb. Its convex, external surface (that wl coalesces with the uterus) is very uneven, and tufted. internal, concave surface (that which is turned towards cavity of the egg) is quite smooth, and clothed by the amı (Fig. 198, *a*). From near the centre of the placenta spr the navel cord (*funiculus umbilicalis*), the developn of which we have already observed (vol. i. p. 383). It al coated by the amnion as with a sheath, which at the n end passes directly into the abdominal skin (Fig. 200, 2 The mature navel cord is a cylindrical cord, coiled spir around its axis, and usually about 20 inches long and ½ thick. It consists of gelatinous connective tissues ("W

's jelly"), in which are contained the remnants of the k-vessels and of the great navel vessels; the two navel eries which convey the blood of the embryo to the pla- ta, and the great navel vein which brings back the blood m the latter to the heart. The numerous fine branches these embryonic navel vessels pass into the branched rion-tufts of the fœtal placenta, and with these, finally, w, in a very peculiar way, into large blood-filled cavities, ich spread themselves in the uterine placenta and con- n blood from the mother. The anatomical relations, very nplex and difficult to comprehend, which are developed ween the embryonic and the maternal placenta, exist in s form only in Man and in the higher Apes, while in all er Deciduous Animals their form is more or less different. e navel cord, also, is proportionately longer in Man and Apes than in other Mammals.

As in these important characters, so also in every other rphological respect, Man appears as a member of the ler of Apes, and cannot be separated from the latter. The at originator of systematic description of nature, Karl nnæus, with prophetic penetration, united Men, Apes, mi-apes, and Bats in a single natural division, under the me of Primates, that is, the first, the lords of the animal gdom. Later naturalists dissolved this order of Primates. e Göttingen anatomist, Blumenbach, first placed Man in pecial order, which he called that of Two-handed Animals *imana*); in a second order, he united Apes and Semi- s under the name of Four-handed Animals (*Quad- mana*), while a third order included the distantly related s (*Chiroptera*). The separation of the Bimana and adrumana was retained by Cuvier and most succeeding

zoologists. It seems very important, but is really w
unjustifiable. This was first shown in the year 18(
Huxley. Supported by very accurate Comparative A
mical researches, he proved that Apes are as "two-ha
as Men, or, conversely, that Men are as "four-hande
Apes. Huxley showed, with convincing clearness, th
ideas previously held of the hand and the foot were
and were incorrectly founded on physiological instead
morphological distinctions. The circumstance that i
hand, the thumb may be opposed to the other four fi
thus permitting the act of grasping, appeared especi
distinguish the hand from the foot, in which the corre
ing great toe cannot be thus opposed to the four rem
toes. Apes, on the contrary, can grasp in this way wi
hind-foot as well as with the fore-foot, and were the
regarded as four-handed. Many tribes, however, amo
lower races of men, especially many negro tribes, use t
in the same way as the hand. In consequence of early
and continued practice, they are able to grasp as wel
the foot as with the hand (for example, in climbing
grasp the branches of trees). Even new-born children
own race have a very strong grasping power in the gre
with which they can hold a spoon as fast as with the
The physiological distinction between hand and foo
therefore, neither be strictly carried out, nor scienti
established. Morphological characters must be used f
purpose.

A sharp morphological distinction of this kind—t
one founded on anatomical structure—between han
foot, between the anterior and the posterior limbs, is ac
possible. There are essential and permanent diffe

n the structure of the bony skeleton and in that of
iscles which are attached to the hand and the foot;
ese are exactly the same in Man and in the Ape.
s, for instance, an essential difference in the arrange-
nd number of the wrist-bones of the hand (*carpus*)
ankle-bones of the foot (*tarsus*). The muscle-masses
equally constant differences. The posterior ex-
, the foot, has always three muscles (a short flexor
a short extensor muscle, and a long muscle attached
muscles of the tibia) which are never present in
erior extremity, the hand. The disposition of the
is also very different in the two sets of limbs.
characteristic differences between the anterior and
terior extremities occur in Man just as in Apes.
an, therefore, be no doubt, that the foot of the
serves the name as truly as that of the Man; and
true Apes are as genuinely two-handed animals
a) as Man. Thus the usual distinction of the Apes
rumana is wholly unjustifiable.

ight now be asked whether, quite apart from these,
e not other marks by which Man is more widely
d from the Apes than are the different species of
om each other. Huxley has given a final negative
question so convincingly, that the opposition now
gainst him in many quarters must be regarded as
ly unfounded and ineffective. Based on an accurate
the Comparative Anatomy of all parts of the body,
brought forward very significant proof that, in
atomical respect, the differences between the highest
lowest Apes are greater than the corresponding
es between the highest Apes and Man. He there-

fore restored Linnæus's order of Primates (excluding th Bats), and divided it into three different sub-orders, th first of which is formed by the Semi-apes (*Lemurida*), th second by the true Apes (*Simiadæ*), and the third by M (*Anthropidæ*).[161]

Yet, if we proceed logically and without prejudice, accordance with the principles of scientific reasoning, find, on the basis of Huxley's own law, this division adequate, and must go considerably further. As I f showed in 1866, in treating this question in my *Gener Morphologie*, we are fully justified in taking at least important step further, in assigning to Man his natu place in one of the divisions of the Ape-order. All characters distinctive of this one division of the Apes present in Man, while they are absent in other Apes. are, therefore, not justified in forming a distinct order Man apart from the true Apes.

The order of the true Apes (*Simiæ*), the Semi-apes be excluded, has long been divided into two natural m groups, which, among other points, are distinguished their geographical distribution. Those of one divi (*Hesperopitheci*, or Western Apes) live in the New Wo in America. The other division, to which Man belong that of the *Heopitheci*, or Eastern Apes; these live in Old World, in Asia, Africa, and, formerly, in Europe. the Apes of the Old World, all Heopitheci, share, in comm with Man, all those characteristics to which special pron ence is justly given, in distinguishing these two group Apes, in zoological classification; among these characteris the structure of the teeth is most prominent. The ob tion is at once evident that the teeth are, in a physiolog

, much too subordinate a part of the body to justify so a weight being attached to their structure in so im- nt a question. There are, however, good reasons for prominent consideration of the structure of the teeth; it is with perfect correctness and propriety that sys- tic zoologists have, for more than a century, given al weight to this character in systematically dis- ishing and arranging the mammalian orders. The ber, form, and disposition of the teeth are transmitted more accurately within the respective orders of the mals than are most other zoological characteristics. structure of the human teeth is well known. In matu- here are 32 teeth in our jaws, and of these 32 teeth, front-teeth, 4 canine-teeth, and 20 molar-teeth. The front-teeth or incisors (*dentes incisivi*), which are ted in the centre of the jaws, exhibit characteristic ences in the upper and lower jaw. In the upper the incisors are larger than the outer; in the lower jaw, he contrary, the inner incisors are smaller than the . Next to these, on each side, both in the upper and r jaw, is a corner-tooth, which is larger than the in- s, the so-called eye-tooth, or canine (*dens caninus*). times this tooth becomes very prominent in Men, as in Apes and many other Mammals, and forms a sort of Finally, next to this, on each side, and in each jaw, ituated five back-teeth, or molar-teeth (*dentes molares*), hich the two foremost (the bicuspid teeth) are small, but a single fang, and are subject to the change of , while the three hinder molars are much larger, have ngs, and do not appear till after the temporary teeth been shed (so-called "grinders"). The Apes of the

Old World have exactly this human structure of the teeth,—all Apes which have as yet been found, either living or as fossils, in Africa, Asia, and Europe. All Apes of the New World, on the contrary, all American Apes, have an extra tooth on both sides of each jaw; this is a biscupid tooth. Thus they have six back-teeth on both sides of each jaw,—in all, thirty-six teeth. This characteristic difference between the Eastern and Western Apes has been so constantly transmitted within the two groups, that it is of the greatest value to us. A small family of South American Apes does, indeed, appear to form an exception in this respect. The pretty little Silk Apes, or Marmosets (*Hapalida*), namely, to which the Brush-monkey (*Midas*) and the tufted Marmoset (*Jacchus*) belong, have but five back-teeth in each half of the jaw, instead of six, and, accordingly, seem to approach nearer the Eastern Apes. But on closer observation it is found that, like all the Western Apes, they have the three biscupids, and that the hindmost grinder has been lost. Thus this apparent exception confirms the value of the distinction.

Among the other marks by which the two main groups of the Apes are distinguished, the structure of the nose is specially important and prominent. In all Old World Apes the structure of the nose is the same as in Man; namely, a comparatively narrow partition of the two halves, so that the nostrils are directed downwards. In a few Eastern Apes, the nose projects as prominently and is as characteristically formed as in Man. We have already called attention, in this respect, to the remarkable Nose-ape (*Semnopithecus nasicus*), which has a well-curved and long nose (Fig. 202). Most of the Eastern Apes have, it is true, a

somewhat flatter nose, as, for instance, has the white-nosed Sea-cat (*Cercopithecus petaurista*, Fig. 203); yet in all the partition of the nose is narrow and thin. On the contrary, all American Apes have a different nasal structure. In them, the partition is peculiarly broadened and thickened below, and the wings of the nose are not developed, in consequence of which the nostrils are not below, but are turned outwards. This characteristic difference in the structure of the nose has also been so accurately trans-

FIG. 202.—Head of Nose-ape (*Semnopithecus nasicus*).
FIG. 203.—The white-nosed Sea-cat (*Cercopithecus petaurista*).

mitted in both groups, that, on account of it, the Apes of the New World have been called Flat-nosed (*Platyrhinæ*), and those of the Old World Narrow-nosed (*Catarhinæ*). The former are, on the average, inferior in organization.

The division of the order of Apes into two sub-orders, the *Platyrhinæ* and the *Catarhinæ*, is, on account of the constant hereditary characters, now generally accepted by zoologists, and receives much support from the geographical distribution of the two groups between the New and Old Worlds. From this follows the direct inference, very important in its bearing on the Phylogeny of Apes, that, from the primæval common parent-form of the Ape-order, two diverging lines branched out at a very early period, one of which spread over the New World, the other over the Old. It is certain that all the Flat-nosed Apes, on the one hand, are descendants of a common parent-form, and, on the other hand, all the Narrow-nosed Apes from another.

An inference concerning our own pedigree may be drawn from this. Man has exactly the same characters, the same peculiar formation of the teeth and nose, as all the Catarhinæ, and is as thoroughly distinguished by these characteristics from the Platyrhinæ. We are therefore compelled, in classifying the Primates, to assign to Man a place in the Narrow-nosed group. The bearing of this on our tribal history is, that Man is immediately related in blood to the apes of the Old World, and may be traced from a parent-form common to all other Catarhinæ also. Man is a genuine Narrow-nosed Ape in his whole structure and in origin, and has descended from some unknown, extinct Catarhine form in the Old World. On the other hand, the Apes of the New World, the Flat-nosed group, constitute a diverging branch of our family tree, and stand in no near genealogical relation to the human race.

We have now reduced the circle of our nearest allies to the small group, containing comparatively few forms,

h is represented by the sub-order of the Narrow-nosed, 'astern Apes. Finally, the question which now re- s to be answered is—what position in this sub-order be assigned to Man, and whether other inferences as e structure of our immediate ancestors may be drawn this position. The comprehensive and acute researches the Comparative Anatomy of Man and the various rhinæ, which Huxley has recorded in his work on the dence as to Man's Place in Nature," are of the greatest in furnishing the answer to these important questions. inevitable conclusion is, that the difference between and the highest Narrow-nosed Apes (the Gorilla, Chim- ee, Orang) is slighter in every respect than the corre- ding differences between the highest and the lowest rhines (the Sea-cat, Macaque, Baboon). Even within small group of the Tail-less man-like Apes (*Anthro- es*) the several genera do not differ less from each other they do from Men. This is seen by a glance at the tons represented here, as arranged by Huxley (Figs. -208). If the skull, or the vertebral column, together the rib-system, or the anterior or posterior members, compared; or if the comparison is extended to the cular system, the circulatory system, the brain, etc., ndid and unprejudiced examination always results in same conclusion, that Man does not differ more from higher Catarhines than the extreme forms of the latter example, the Gorilla and Baboon) differ from each r. We can, therefore, complete the important propo- n already quoted from Huxley: We may take what- system of organs we will,—the comparison of their ifications within the ranks of the Catarhinæ leads us

Fig. 204. (Cf. p. 181.) Gibbon.

Fig. 205. (Plate XIV Fig. 3.) Orang-outang.

Fig. 206. (Plate XIV. Fig. 1.) Chimpanzee.

Fig. 207. (Plate XIV. Fig. 2.) Gorilla.

Fig. 208. (Plate XIV Fig. 4.) Man.

o one and the same conclusion: that the anatomical differences that distinguish Man from the most highly developed Catarhinæ (the Orang, Gorilla, Chimpanzee), are not so great as those which separate the latter from the lowest Catarhinæ (Sea-cat, Macaque, Baboon).

We must, therefore, consider the proof complete, that Man is descended from other Narrow-nosed Apes (*Catarhinæ*). Although future researches into the Comparative Anatomy and Ontogeny of the existing Catarhines, as well as of their fossil relatives, promise us various new details, yet no future discovery can ever overthrow that important proposition. Our Catarhine ancestors must, of course, have passed through a long series of varied forms, before Man finally developed as the most perfect form. The following must be considered as the most important advances by which this "Creation of Man," his differentiation from the most nearly allied Catarhine Apes, was effected: Habituation to upright carriage and, in connection with this, the greater differentiation of the anterior and posterior limbs; also, the development of articulate speech and its organ, the larynx; and lastly, and especially, the more perfect development of the brain and its function, the soul; sexual selection must have exerted an extraordinarily important influence, as Darwin has conclusively proved in his celebrated work on sexual selection.[162]

With reference to these advances, we may, among our Catarhine ancestors, distinguish at least four important ancestral stages, marking prominent epochs in the great historical process of the origin of Man. As the nineteenth stage in the human pedigree, next to the Semi-apes, we may place the oldest and lowest Catarhine Apes, which developed

from the former by the formation of the characteristic catarhine head, and by the peculiar modification of the teeth, the nose, and the brain. This oldest parent-form of the whole Catarhine group must, certainly, have been thickly covered with hair, and must have had a long tail; was, in fact, a Tailed Ape (*Menocerca*, Fig. 203). They were already in existence during the earlier part of the Tertiary Epoch (during the Eocene Period), as is shown by fossil remains of Eocene Catarhines. Among extant Tailed Apes, the Slender Apes (*Semnopitheci*) are perhaps most nearly related to this parent-form.[163]

As the twentieth stage in the human pedigree, next to these Tailed Apes, we must rank the Tail-less man-like Apes (*Anthropoides*), under which name the most highly developed Catarhines, those most nearly related to Man, have been grouped. They originated from the Tailed Catarhines, by the loss of the tail, the partial loss of their hairy covering, and the further development of the brain, the latter being indicated in the preponderating development of the brain-skull over the facial skull. At the present time but few forms of this remarkable family are in existence; they are distributed into two different groups, an African and an Asiatic group. The African Man-like Apes are limited to the western part of tropical Africa, but are probably distributed over Central Africa in several species. Only two species are well known: the Gorilla (*Pongo gorilla*, or *Gorilla engina*), the largest of all Apes (Fig. 207); and the smaller Chimpanzee (*Pongo troglodytes*, or *Engeco troglodytes*), which may be seen in several zoological gardens (Figs. 206, Plate XIV. Figs. 1, 2). Both the African Man-like Apes are black in colour, and like their countrymen,

1. Chimpanzee.
2. Gorilla.
3. Orang.
4. Negro.

he Negroes, have the head long from back to front (dolichocephalic). The Asiatic Man-like Apes are, on the contrary, mostly of a brown, or yellowish brown colour, and have the head short from back to front (brachycephalic), like their countrymen, the Malays and Mongols. The largest Asiatic Man-like Ape is the well-known Orang, or Orang-outang (Fig. 128), which is indigenous in the Sunda Islands (Borneo, Sumatra), and is brown in colour. Two species have recently been distinguished: the great Orang (*Satyrus Orang*; Fig. 205, Plate XIV. Fig. 3), and the small Orang (*Satyrus morio*). A genus of smaller Anthropoids (Fig. 204), the Gibbons (*Hylobates*), live on the main-land of Southern Asia and on the Sunda Islands; from four to eight different species of these have been distinguished. Neither of these living Anthropoids can be indicated as the Ape absolutely most like Man. The Gorilla approaches nearest to Man in the structure of the hand and foot, the Chimpanzee in important structural details in the skull, the Orang in the development of the brain, and the Gibbon in that of the thorax. It is evident that no single one of these existing Man-like Apes is among the direct ancestors of the human race; they are all the last scattered remnants of an old, catarhine branch, once numerous, from which the human race has developed as a special branch and in a special direction.

Although Man (*Homo*) ranks immediately next to this anthropoid family, from which he doubtless directly originated, yet the Ape-men (*Pithecanthropi*) may be inserted here, as an important intermediate form between the two, and as the twenty-first stage in our ancestral series. In the "Natural History of Creation" (vol. ii. p. 293), I have

applied this name to the speechless Primitive Men (*Ala*
who made their appearance in what is usually called t
human form, that is, having the general structure of l
(especially in the differentiation of the limbs)—but y
being destitute of one of the most important qualities
Man, namely, articulate speech, as well as of the high
mental development connected with speech. The high
differentiation of the larynx and of the brain occasioned b
the latter, first gave rise to the true "Man."

Comparative Philology has recently shown that th
present human language is polyphyletic in origin, th
several, and probably many, different original languag
must be recognized, as having developed independently fro
each other. The history of the development of languag
also teaches us (its Ontogeny in every child, as well as
Phylogeny in every race), that the actual rational la
guage of men developed gradually, only after the bo
had developed into the specific human form. It is ev
probable that the formation of language did not begin
after the differentiation of the various species, or races
men, and this presumably occurred in the beginning of t
Quaternary Epoch, or the Diluvial Period. The Ape-m
or *Alali*, were therefore probably already in existe
toward the close of the Tertiary Epoch, during the Plioc
Period, perhaps even as early as the Miocene Period.[164]

Lastly, the genuine or speaking human being (*Ho*
must be considered as the twenty-second and final st
in our animal pedigree. Man originated from the p
ceding stage in consequence of the gradual improvem
of inarticulate animal sounds into true human articul
speech. Only very uncertain conjectures can be formed

the time and place of this true "Creation of Man." is probable that Primæval Man originated during the avial Epoch, in the torrid zone of the Old World, either the continent of tropical Asia or Africa, or on an earlier ntinent which has now sunk below the surface of the Indian ean, and which extended from Eastern Africa (Madagas- r and Abyssinia) to Eastern Asia (the Sunda Islands d Eastern India). In my "Natural History of Creation" hapter XXIII. and Table XV.), I have already fully scussed the important evidence as to the former existence this large continent, called Lemuria, and how the distribu- n of the various species and races of men probably took ace from this "Paradise" over the surface of the earth. the same place, I have also fully discussed the inter- lations of the various races and species of the human ce.[163]

TABLE XXII.

SYSTEMATIC SURVEY OF THE PERIODS IN THE TRIBAL HISTORY OF HUMAN RACE.

(Compare Table VIII., vol. i. p. 402.)

FIRST MAIN PERIOD IN TRIBAL HISTORY.

The Plastid Ancestors of Man.

The form of the ancestors of man is equal to the simple individual of first order, a **single plastid.**

First Stage: **Moneron Series** (Fig. 163, p. 46).

The ancestors of man are single, living, **simple cytods.**

Second Stage: **Amœba Series** (Fig. 167 p. 53).

The ancestors of man are single, living, **simple cells.**

SECOND MAIN PERIOD IN TRIBAL HISTORY.

The many-celled Primitive Animal Ancestors of Man.

The ancestors of man consist of a closely-united society of many h geneous cells; hence their form-value is that of individuals of the se order, of **Idorgana.**

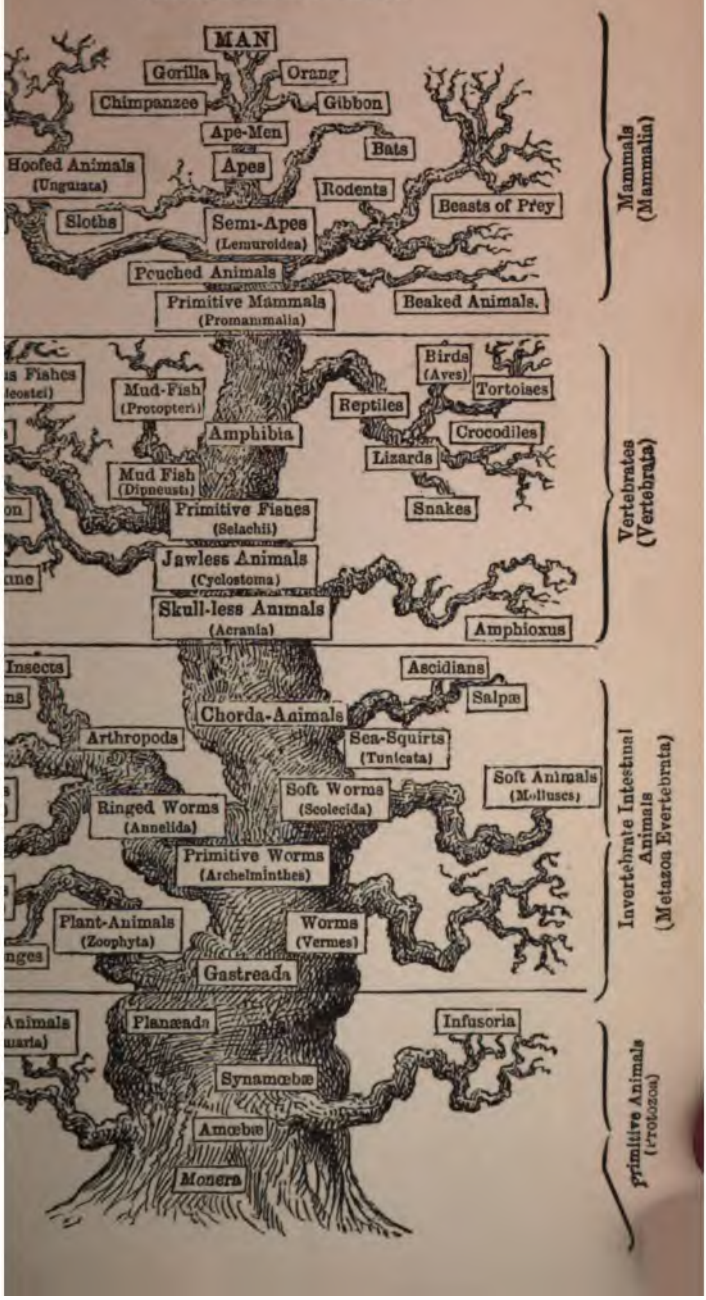
Third Stage: **Synamœba Series** (Fig. 170, p. 55).

The ancestors of man are many-celled primitive animals of the sim kind: solid masses of simple, homogeneous cells.

Fourth Stage: **Planæa Series** (Figs. 172, 173, p. 60).

The ancestors of man are many-celled primitive animals of a char like that of the *Magosphæra* and certain planula-larvæ, of equal rank the ontogenetic *Blastula* or *Blastosphæra*; hollow spheres, the wall of w consists of a single stratum of ciliated cells.

PEDIGREE OF MAN.



THIRD MAIN PERIOD IN TRIBAL HISTORY.

The Invertebrate Intestinal Animal Ancestors of Man.

The ancestors of man have the form-value of individuals of the **third** rder, of **inarticulate individuals.** The body encloses an intestinal cavity ith a mouth, and consists at first of two primary germ-layers, afterwards f four secondary germ-layers.

Fifth Stage: **Gastræa Series** (Figs. 174–179, p. 65).

The ancestors of man have the form-value and structure of a **Gastrula.** The body consists merely of a simple primitive intestine, the wall of which s formed of the two primary germ-layers.

Sixth Stage: **Chordonium Series** (Figs. 184–188, p. 80–90).

The ancestors of man are **worms**: at first, primitive worms, allied to the *Turbellaria;* afterwards worms of higher rank, *Scolecida;* finally, notochord-animals with the organization of the ascidian larvæ. The body is composed of four secondary germ-layers.

FOURTH MAIN PERIOD IN TRIBAL HISTORY.

The Vertebrate Ancestors of Man.

The ancestors of man are vertebrates, and their form-value is, therefore, that of **an articulated individual,** or **a chain of metamera.** The skin-sensory layer is specialized into the horn-plate, medullary tube, and primitive kidneys. The skin-fibrous layer has divided into the leather-plate, primitive vertebræ (muscular plate and skeleton-plate), and the notochord. From the intestinal-fibrous layer originates the heart with the main blood-vessels and the fleshy intestinal wall. From the intestinal-glandular layer, the epithelium of the intestinal tube is formed. The formation of metamera is constant.

Seventh Stage: **Acrania Series** (Fig. 189; Pl. XI. Fig. 15).

The ancestors of man are **skull-less vertebrates,** like the extant **Amphioxus.** The body already forms a chain of metamera, several primitive vertebræ having separated off. The head is not yet entirely distinct from the trunk. The medullary tube has not separated into brain-bladders. The heart is very simple, without chambers. The skull is still wanting; as are also the jaws and limbs.

Eighth Stage: **Monorhina Series** (Fig. 190; Pl. XI. Fig. 16).

The ancestors of man are jaw-less **skulled animals** (resembling developed **Myxinoides** and **Petromyzontes**). The number of the metamer increasing. The head is becoming more distinctly differentiated from trunk. The anterior end of the medullary tube swells into a bladder-structure and forms the brain, which is soon differentiated into five br bladders. At the sides of these appear the three higher organs of se The heart is divided into auricle and ventricle. The jaws, limbs, swimming-bladder are still wanting.

Ninth Stage: **Ichthyoda Series** (Figs. 191, 192; Pl. XII. and XIII.).

The ancestors of man are **fish-like skulled animals**: first, **Primi Fishes** (*Selachii*), then **mud-fishes** (*Dipneusta*), then **gilled Batrachians** (*Sora* The ancestors belonging to this Ichthyoda stage develop two pairs of lin a pair of anterior limbs (pectoral fins) and a pair of posterior limbs (ven fins). The gill-arches are formed between the gill-openings, and from tl are formed the first pair of jaw-arches (upper and lower jaws). swimming-bladder (lungs), liver, and pancreas grow from the intest canal.

Tenth Stage: **Amniota Series** (Figs. 195–208; Pl. XIV.).

The ancestors of man are **amnion-animals** or **gill-less vertebrates**: fi **Primitive amniota** (*Protamnia*), then **Primitive mammals** (*Monotrema*); n **Pouched animals** (*Marsupialia*); then **Semi-apes** (*Prosimiæ*), and, las **Apes** (*Simiæ*). The ape-ancestors of man are first tailed *Catarhini*, t tail-less Catarhini (*Anthropoides*), then speechless Ape-men (*Alali*), and last genuine, speaking men. The ancestors belonging to this amnion series develop an amnion and allantois, and gradually acquire the ma malian structure, and at last the specific human form.

TABLE XXIII.

Systematic Survey of the Phylogenetic Classification of Mammals.

I. First class of mammals	Cloacal Animals (*Monotrema*, or *Ornithodelphia*)	1. Primitive Mammals		*Promammalia*
		2. Beaked Animals		*Ornithostoma*
II. Second class of mammals	Pouched Animals (*Marsupialia*, or *Didelphia*)	3. Herbivorous Pouched Animals		*Botanophaga*
		4. Carnivorous Pouched Animals		*Zoophaga*
III. Third class of mammals: placental mammals (*Placentalia*, *Monophia*)	III. (a) Placental Mammals without Decidua, with Tufted Placenta *Indecidua Villiplacentalia*	5. Hoofed Animals *Ungulata*	Single-hoofed	*Perissodactyla*
			Double-hoofed	*Artiodactyla*
		6. Whale-like Animals *Cetomorpha*	Sea-cows	*Sirenia*
			Whales	*Cetacea*
	III. (b) Placental Mammals with Decidua, with Girdle Placenta *Deciduata Zonoplacentalia*	7. Pseudo-hoofed Animals *Chelophora*	Rock Conies	*Lamnungia*
			Elephants	*Proboscidea*
		8. Beasts of Prey *Carnassia*	Land Beasts of prey	*Carnivora*
			Marine Beasts of prey	*Pinnipedia*
	III. (c) Placental Mammals with Decidua, with Discoid Placenta *Deciduata Discoplacentalia*	9. Semi-apes *Prosimiæ*	Fingered animals	*Leptodactyla*
			Long-footed	*Macrotarsi*
			Flying Lemur	*Ptenopleura*
			Lemurs	*Brachytarsi*
		10. Gnawing Animals *Rodentia*	Squirrel species	*Sciuromorpha*
			Mouse species	*Myomorpha*
			Porcupine species	*Hystrichomorpha*
			Hare species	*Lagomorpha*
		11. Toothless *Edentata*	Digging animals	*Effodientia*
			Sloths	*Bradypoda*
		12. Insect-eaters *Insectivora*	With Cœcum	*Menotyphla*
			Without Cœcum	*Lipotyphla*
		13. Flying Animals *Chiroptera*	Flying Foxes	*Pterocynes*
			Bats	*Nycterides*
		14. Apes *Simiæ*	Flat-nosed	*Platyrhinæ*
			Narrow-nosed Apes	*Catarhinæ*

TABLE XXIV.

Pedigree of Mammals.

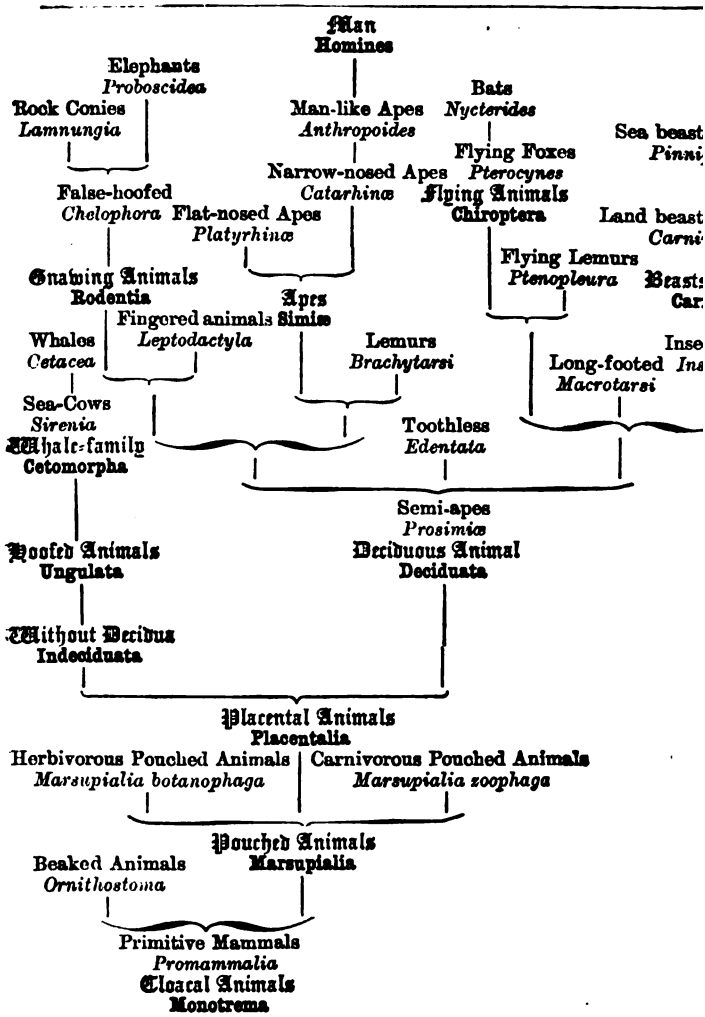
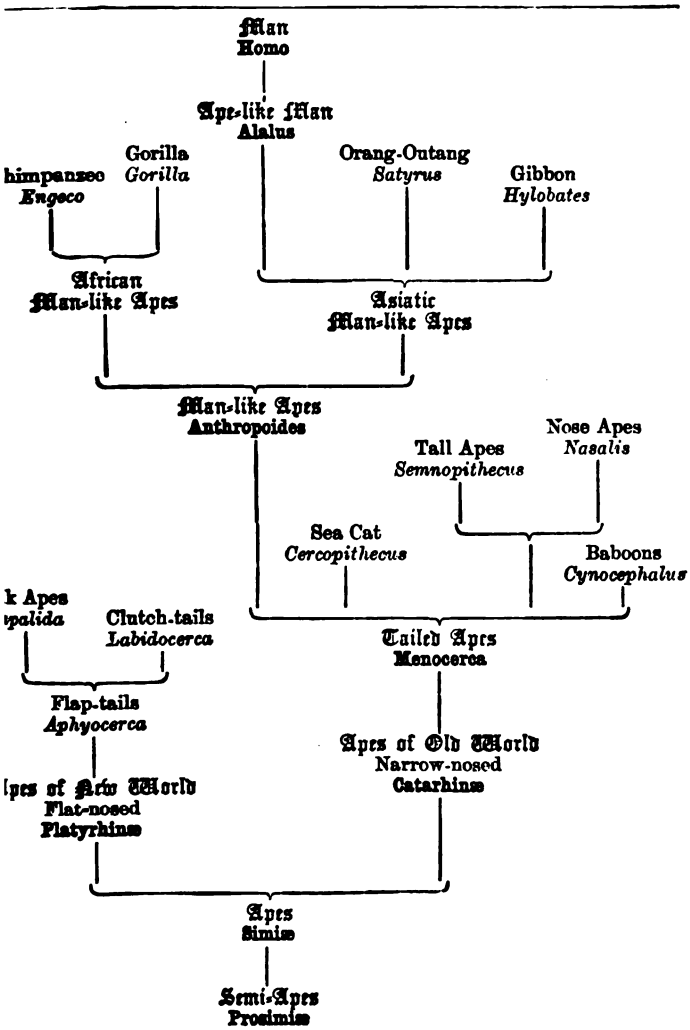


TABLE XXV.

Pedigree of Apes.



CHAPTER XX.

THE HISTORY OF THE EVOLUTION OF THE EPIDERMIS AND THE NERVOUS SYSTEM.

Animal and Vegetative Organ-systems.—Original Relations of these to the Two Primary Germ-layers.—Sensory Apparatus.—Constituents of Sensory Apparatus: originally only the Exoderm, or Skin-layer; afterwards, the Skin-covering specialized from the Nerve-system.—Double Function of the Skin (as a Covering and as Organ of Touch).—Outer Skin (*Epidermis*) and Leather-skin (*Corium*).—Appendages of the Epidermis: Skin-glands (Sweat-glands, Tear-glands, Sebaceous Glands, Milk-glands); Nails and Hair.—The Embryonic Wool-covering.—Hair of the Head and of the Beard.—Influence of Sexual Selection.—Arrangement of the Nerve-system.—Motor and Sensory Nerves.—Central Marrow: Brain and Dorsal Marrow.—Constitution of the Human Brain: Large Brain (*Cerebrum*) and Small Brain (*Cerebellum*).—Comparative Anatomy of the Central Marrow.—Germ-history of the Medullary-tube.—Separation of the Medullary-tube into Brain and Dorsal Marrow.—Modification of the Simple Brain-bladder into Five Consecutive Brain-bladders: Fore-brain (Large Brain, or *Cerebrum*), Twixt-brain ("Centre of Sight"), Mid-brain ("Four Bulbs"), Hind-brain (Small Brain, or *Cerebellum*), After-brain (Neck Medulla).—Various Formation of the Five Brain-bladders in the various Vertebrate Classes.—Development of the Conductive Marrow, or "Peripheric Nervous System."

"Hardly any part of the bodily frame, then, could be found better calculated to illustrate the truth that the structural differences between Man and the highest Ape are of less value than those between the highest

be lower Apes, than the hand or the foot, and yet, perhaps, there is one which enforces the same conclusion in a still more striking manner—hat is the brain."—*Man's Place in Nature*, p. 94 (1863).

As if to demonstrate, by a striking example, the impossibility of ng any cerebral barrier between Man and the Apes, Nature has led us, in the latter animals, with an almost complete series of gra-ns, from brains little higher than that of a Rodent to brains little lower hat of Man."—*Ibid.* p. 96.

investigations, up to the present, have shown us how whole human body has developed from an entirely simple nning, from a single simple cell. The whole human as well as the individual man, owes its origin to a le cell. The one-celled parent-form of the former is, even reproduced in the one-celled germ-form of the latter. onclusion, we must glance at the evolutionary history of separate parts which constitute the human body. In matter, I must, of course, restrict myself to the most ral and important outlines; for a detailed study of the itionary history of the separate organs and tissues d occupy too much space, and would demand a greater it of anatomical knowledge than the generality of my rs are likely to possess. In considering the develop-of the organs, and of their functions, we will retain the od previously employed, except that we will consider erm-history and the tribal history of the various parts e body in common. In the history of the evolution of uman body as a whole we have found that Phylogeny where serves to throw light on the obscure course of geny, and that the clew afforded by phylogenetic con-ty alone enables us to find our way through the labyrinth togenetic facts. We shall experience exactly the same in the history of the development of the separate

organs, but I shall be compelled to explain the ontoge and the phylogenetic origin of the organs simultaneo for the further we penetrate into the details of or development, and the more minutely we study the o of the separate parts, the more clearly do we see inseparably the evolution of the germ is connected that of the tribe. The Ontogeny of the organs is intell and explicable only through their Phylogeny; just a germ-history of the entire body (the "person") is ren intelligible only by the history of the tribe. Each form is determined by a corresponding ancestral form. is as true of the parts as of the whole.

In endeavouring, with the help of this fundament of Biogeny, to obtain a general view of the main featu the development of the separate organs of man, we m the first place, consider the animal, and then the vege organ-systems of the body. The first main group of o the animal organ-systems, is formed by the sensory app together with the motor apparatus. To the former l the skin-covering, the nervous system, and the organs senses. The motor apparatus consists of the passive of movement (the skeleton) and the active organ muscles). The second main group of organs, the vege organ-system, is formed by the nutritive and the ductive apparatus. To the nutritive apparatus b especially the intestinal canal with all its appen together with the vascular and renal systems. The ductive apparatus includes the various sexual organ germ-glands, germ-ducts, organs of copulation, etc.).

In earlier chapters (IX. and X.) it has been state the animal organ-systems (the instruments of sensati

ıovement) proceed especially from the outer primary -layer, from the skin-layer. The vegetative organ- ıns, on the other hand (the instruments of nutrition and duction), proceed principally from the inner primary -layer, from the intestinal layer. This radical contrast een the animal and the vegetative spheres of the body is true, by no means absolute either in man or in the r animals; on the contrary, many separate parts of the al apparatus (*e.g.*, the intestinal nerve, or sympathetic) ıated from cells which have proceeded from the ento- ; and, on the other hand, a large part of the vegetative atus (*e.g.*, the mouth-cavity, and probably the greater of the urinary and sexual organs) is formed of cells ı are originally derived from the exoderm. Moreover, bodies of all the more highly developed animals, the heterogeneous parts are so intermixed and blended it is often extremely difficult to assign its true source h one of the constituent parts. But, on the whole, we assume as a certain and important fact, that in Man, ı all high animals, the greater part of the animal organs be referred to the skin-layer, or exoderm; the greater of the vegetative organs to the intestinal layer, or erm. For this reason, Baer called the former the ıl germ-layer, the latter, the vegetative germ-layer ol. i. pp. 53 and 196). Of course, in making this important ıption, we pre-suppose the correctness of Baer's view, ling to which the skin-fibrous layer (the "flesh ın" of Baer) must have originated (phylogenetically) the exoderm, and, on the other hand, the intestinal- s layer (Baer's "vascular layer") from the entoderm. ıis influential view, which is yet much disputed, is, we

TABLE XXVI.

Systematic Survey of the Organ-Systems of the Human Body.

(N.B.—The origin of the separate organs from the four secondary layers is indicated by the Roman numerals (I.–IV.): I. Skin-sensory II. Skin-fibrous layer; III. Intestinal-fibrous layer; IV. Intestinal ular layer.)

ANIMAL ORGAN-SYSTEM.	A. Sensory Apparatus *Sensorium*	1. Skin-covering (*Derma*)	Outer skin	Epidermis, I.
			Leather skin	Corium, II.
		2. Central nerve-system	Brain	Encephalon
			Spinal marrow	Medulla spinal
		3. Peripheric nerve-system	Brain nerves	Nervi cerebral
			Spinal nerves	Nervi spinales
			Intestinal nerves	Sympatheticu
		4. Sense-organs (*Organa sensuum*)	Organ of touch (skin)	Org. tactus
			Organ of taste (tongue)	Org. gustus
			Organ of smell (nose)	Org. olfactus
			Organ of sight (eye)	Org. visus
			Organ of hearing (ear)	Org. auditus
	B. Motive Apparatus *Locomotorium*	5. Muscle-system (active motive organs)	Skin muscles	Musculi cutan
			Skeleton muscles	M. skeleti
		6. Skeleton-system (passive motive organs)	Vertebral column	Vertebrarium
			Skull	Cranium
			Limb skeleton	Sk. extremitat
VEGETATIVE ORGAN-SYSTEM.	C. Nutritive Apparatus *Nutritorium*	7. Intestinal system (*Gaster*)	Digestive organ	O. digestiva
			Respiratory organ	O. respiratoria.
		8. Vascular system (*Organa circulationis*)	Body cavity	Cœloma, II.
			Lymph vessels	Vasa lymphatica
			Blood vessels	V. sanguifera
			Heart	Cor, III.
		9. Renal system (*Organa urinaria*)	Kidneys	Renes } I. (
			Urinary ducts	Ureteres }
			Urinary bladder	Urocystis, III
	D. Reproductive Apparatus *Propagatorium*	10. Sexual organs (*Organa sexualia*)	Sexual glands	Gonades
			(I. Ovary)	(I. Ovaria) III
			(II. Testes)	(II. Testes) I.
			Sexual ducts	Gonophori
			(I. Oviduct)	(I. Oviductus)
			(II. Seed duct)	(II. Spermaductus)
			Copulatory organs	Copulativa
			(I. Sheath)	(I. Vagina)
			(II. Penis)	(II. Penis)

think, securely founded on the Gastrula—that most important of all the germ-forms of the animal kingdom—which we find recurs in similar form in the germ-history of the most different classes of animals. This significant germ-form points unmistakably to a parent-form (the Gastræa) common to all animals, the Protozoa alone excepted; in this long extinct parent-form the entire body of the animal consisted throughout life of the two primary germ-layers, as is yet the case, for a short time, in the Gastrula. In the Gastræa the simple skin-layer did *actually* represent all the animal organs and functions, and the simple intestinal layer, on the other hand, all the vegetative organs and functions; potentially, this is even yet the case in the Gastrula.

In studying the development of the first important part of the animal sphere, the sensory apparatus, or sensorium, we shall now find how well adapted this Gastræa theory is to explain, not only in a morphological but in a physiological sense, the most important facts in the history of evolution. This sensory apparatus consists of two very distinct parts, having, apparently, nothing in common: in the first place, the external skin-covering (*Derma*), together with its appendages, the hair, nails, sweat-glands, etc.; and, secondly, the nervous system, situated internally. The latter includes the central nervous system (brain and spinal chord), the peripheric brain-nerves and medullary nerves, and finally, the organs of sense. In the fully developed vertebrate body these two main constituents of the sensorium are entirely separate; the skin lying entirely externally on the body, while the central nervous system within, and quite separate from the former. The two are connected merely by a portion of the peripheric nerve-

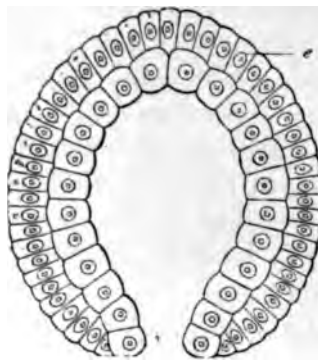
system and of the sense-organs. And yet, as we al know from the germ-history of man, the latter is deve from the former. Those organs of our body which disc the highest and most perfect functions of animal life— of sensation, volition, thought—in a word, the orgi the psyche, of mental life—arise from the external covering.

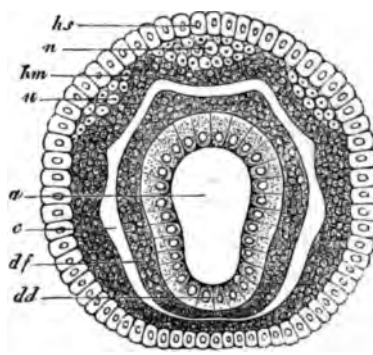
This remarkable fact, considered in itself alone, see wonderful, inexplicable, and paradoxical, that the truth fact was simply long denied. The most trustworthy en logical observations were met with the erroneous stat that the central nerve-system develops, not from the germ-layer, but from a special cell-layer lying under this. The ontogenetic fact would not, however, yield now that Phylogeny has thrown light on the subje fact seems perfectly natural and necessary. Whe reflect on the historic evolution of mind and sense acti we must necessarily conceive the cells, which accor these, as originally situated on the outer surface animal-body. Such externally placed elementary could alone directly receive and deal with impressions the outer world. Afterwards, under the influen natural selection, the complex cell-masses which had b especially "sensitive" gradually withdrew into the she the interior of the body, and there laid the first found of a central nervous organ. As differentiation adv the distance and distinction between the external covering and the central nervous system detached fron became continually greater, and finally the two wer manently connected merely by the conductive peri nerves.

This view is fully confirmed by the results of Comparative Anatomy. Comparative Anatomy shows that many lower animals possess no nervous system, although, in common with higher animals, they exercise the functions of sensation, volition, and thought. In the Primitive Animals (*Protozoa*), which do not even form germ-layers, of course the nervous system, like the skin-covering, is wanting. Even in the second main division of the animal kingdom—in the Metazoa or Intestinal Animals—there is at first no nervous system. The functions of these are performed by the simple cell-layer of the exoderm, which the lower Intestinal Animals have inherited directly from the Gastræa (Fig. 209, *e*). This is the case in the lowest Plant Animals (*Zoophyta*), the Gastræads, Sponges, and the lowest Hydroid Polyps, which are but little higher than the Gastræads. Just as all the vegetative functions of these are performed by the simple intestinal layer, so all the animal functions are discharged by the equally simple skin-layer. The simple cell stratum of the exoderm is, in these, skin-covering, motive apparatus, and nervous system simultaneously.

Most probably the nervous system was also wanting in a large proportion of those Primitive Worms (*Archelminthes*) which were developed directly from the Gastræads. Even those Primitive Worms in which the two primary germ-layers had already split into the four secondary germ-layers (Plate V. Fig. 10), seem not to have possessed a nervous system distinct from the skin. The skin-sensory layer must, even in these long-extinct Worms, have been at once skin-covering and nerve-system. But already in the Flat Worms (*Platelminthes*), and especially in the Gliding Worms (*Turbellaria*) which of all existing forms approach nearest to the Primitive

Worms, we find an independent nerve-system, distinct and separate from the outer skin-covering. This is the "upper





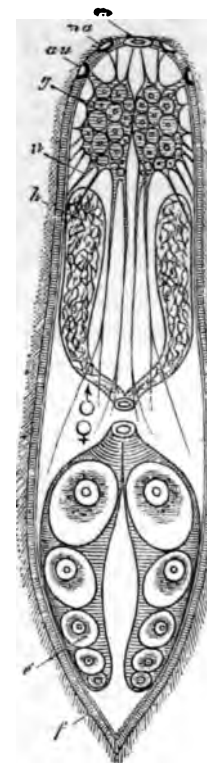


FIG. 209.—Gastrula of Gastrophysema (Gastræad-class).

FIG. 210.—Transverse section through an embryonic Earth-worm: skin-sensory layer; *hm*, skin-fibrous layer; *df*, intestinal-fibrous layer; intestinal-glandular layer; *a*, intestinal cavity; *c*, body-cavity, or *Cœlom* *n*, nerve-ganglia; *u*, primitive kidneys.

FIG. 211.—A Gliding Worm (*Rhabdocœlum*). From the brain or up throat ganglion (*g*) nerves (*n*) radiate towards the skin (*f*), the eyes (*a* the organ of smell (*na*), and the mouth (*m*): *h*, testes; *e*, ovaries.

throat ganglion," situated above the throat (Fig. 211, *g*; Plate V. Fig. 11, *m*). The complex central nervous system of all higher animals has developed from this simple rudiment. In the higher Worms, *e.g.*, the Earth-worms, according to Kowalevsky, the earliest rudiment of the central nervous system (Fig 210, *n*) is a local thickening of the skin-sensory layer (*hs*), which afterwards, becomes entirely detached from the horn-plate. Even the medullary tube of Vertebrates has the same origin. From the germ-history of Man, we already know that this medullary tube, the commencement of the central nervous system, originally develops from the outer skin-covering.

Let us now turn aside from these very interesting features in evolution, and examine the development of the later human skin-covering, with its hairs, sweat-glands, etc. Physiologically, this outer covering (*derma*, or *tegumentum*) plays a double part. The skin, in the first place, forms the general protective covering (*integumentum commune*) which covers the whole surface of the body, and protects all other parts. As such, it, at the same time, effects a certain exchange of matter between the body and the surrounding atmospheric air (perspiration or skin-breathing). In the second place, the skin is the oldest and most primitive sense-organ, the organ of touch, which effects the sensation of the surrounding temperature and of the pressure or resistance of bodies with which it comes in contact.

The human skin, like that of all higher animals, consists essentially of two distinct parts; of the outer-skin, and of the underlying leather-skin. The outer-skin (*epidermis*) consists only of simple cells, and contains no blood-vessels (Fig. 212, *ab*). It develops from the first of the secondary

germ-layers from the skin-sensory layer, and, directly, from the horn-plate of the latter. The leather-skin (*corium*), on the contrary, consists principally of connective or fibrous

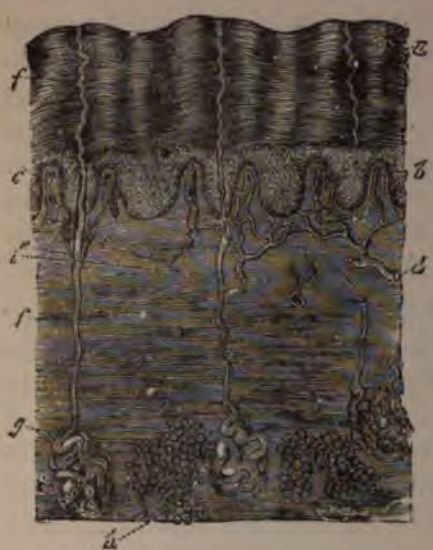


FIG. 212.—Human skin in perpendicular section (after Ecker), much enlarged: *a*, horny stratum of outer-skin (*epidermis*); *b*, mucous stratum of outer-skin; *c*, papillæ of the leather-skin (*corium*); *d*, blood-vessels of the latter; *e*, *f*, excretory ducts of the sweat-glands (*g*); *h*, fat-globules of the leather-skin; *i*, nerve, passing above into a touch-body.

tissue, contains numerous blood-vessels and nerves, and has a different origin. It develops from the outer stratum of the second secondary germ-layer, from the skin-fibrous layer. The leather-skin is much thicker than the outer-skin. In its deeper part, the "*subcutis*," lie many masses of fat-cells (Fig. 212, *h*). Its upper part, the true "*cutis*," or papillary layer, forms, over nearly the whole surface of the body, a number of microscopic cone-shaped warts, or papillæ, which fit into the overlying epidermis (*c*). These touch-warts, or sensory papillæ, contain the most delicate of all the sensory organs of the skin, the "*corpuscula tactus*." Other papillæ

contain merely the terminal loops of the nutritive blood-vessels of the skin (*cd*). All these different parts of the leather-skin originate, by differentiation, from the cells, originally homogeneous, of the leather-plate, the outer lamella of the skin-fibrous layer (Fig. 112, *hpr*, vol. i. p. 352; Plates IV. and V., *l*; Figs. 65–69, *hf*, p. 277).[166]

Analogously, all the constituent parts and appendages of the outer-skin (*epidermis*) originate, by differentiation, from the homogeneous cells of the horn-plate (Fig. 213). At a

FIG. 213.—Cells of the outer-skin (*epidermis*) of a human embryo of two months. (After Koelliker.)

very early period, the simple cell-layer of this horn-plate splits into two distinct strata. The inner, softer stratum (Fig. 212, *b*) is called the mucous layer; the outer, harder stratum (*a*), the horn-layer of the outer-skin. The surface of this horn-layer is continually worn out and thrown off; new cell-strata, produced by the growth of the underlying mucous layer, take its place. Originally the outer-skin forms an entirely simple cover over the surface of the body. Afterwards, however, sundry appendages develop from this both internally and externally. The internal appendages are the skin-glands; the sweat-glands, the sebaceous glands, etc. The external appendages are hair, nails, etc.

The glands of the skin-covering are at first merely solid plug-shaped growths of the outer-skin (*epidermis*), which penetrate into the underlying leather-skin (*corium*) (Fig. 214_1). A canal afterwards forms inside these solid

plugs ($_2$, $_3$), either owing to the softening and breaking up of the central cells, or as the result of a fluid internally secreted. Some of these skin-glands remain unbranched, as for instance, the sweat-glands (*e, f, g*). These glands, which, secrete the sweat, are of great length, their ends forming a coil; they never branch, however; and the same is to be said of the glands which secrete the fatty wax of the ears.

Fig. 214.—Rudiments of tear-glands from a human embryo of four months. (After Koelliker.) 1. Earliest rudiment the shape of a simple, solid plug. 2 and 3. Further developed rudiments, which branch and become hollow: *a*, a solid offshoot; *e*, cell-covering of the hollow offshoot; *f*, rudiment of the fibrous covering, which afterwards forms the leather-skin round the glands.

most other skin-glands give out shoots and branches, as, for instance, the tear-glands, situated on the upper eyelid, which secrete the tears (Fig. 214), and also the sebaceous glands, which produce the fatty sebaceous matter and generally open into the hair-follicles. The sweat and sebaceous glands occur only in Mammals. The tear-glands, on the contrary, are found in all the three classes of Amnion Animals, in Reptiles, Birds, and Mammals. They are not represented in the lower Vertebrates.

Very remarkable skin-glands, found in all Mammals, and in them exclusively, are the milk-glands (*glandulæ mammales*, Figs. 215, 216). They supply milk for the nourishment of the new-born Mammal. Notwithstanding

their extraordinary size, these important organs are merely large sebaceous skin-glands (Plate V. Fig. 16, *md*). The milk is produced by liquefaction of the fatty milk-cells within the branched milk-gland pouch (Fig. 215, *c*), just as the sebaceous matter of the skin, and the fatty matter of the hair are produced by the breaking up of fatty sebaceous cells within the sebaceous skin-glands. The excretory passages of the milk-glands enlarge into sac-like milk-ducts (*b*), which again become narrower (*a*), and open through from sixteen to twenty-four minute apertures, into the nipple of the breast. The first rudiment of this large and complex gland is a very simple conical plug in the

FIG. 215.—The breast of the female in section: *c*, grape-like glandular lobules; *b*, enlarged milk-ducts; *a*, narrow excretory ducts, opening through the breast-nipple. (After H. Meyer.)

FIG. 216.—Milk-glands of a new-born child: *a*, original central gland; *b*, smaller, and *c*, larger branches of the latter. (After Langer.)

of the ordinary epidermic cells. Within this a firm central cellular mass of conical shape soon forms. T increases considerably in length, detaches itself from t surrounding cellular mass, the "root-sheath," and fina makes its way to the outside, appearing above the ou surface as a hair-stem. The deepest part, buried in skin, the hair follicle, is the root of the hair, and is s rounded by the root-sheath. In the human embryo first hairs make their appearance at the end of the fi or in the beginning of the sixth month.

During the last three or four months before birth human embryo is usually covered by a thick coating of d cate woolly hairs. This embryonic wool-covering (*lanu* is often lost during the last weeks of embryonic life, a at any rate, soon after birth, when it is replaced by thinner permanent hair-covering. These later perman hairs grow out of hair follicles which are developed fr the root-sheaths of the deciduous woolly hair. In human embryo, the embryonic woolly hair usually cov the entire body, with the exception of the palms of hands and the soles of the feet. These parts remain ba just as in all Apes and most other Mammals. Not frequently the woolly coat of the embryo differs considera in colour from the later permanent hairy covering. Th for instance, it sometimes happens in our own Indo-G manic race that fair-haired parents are shocked to fi their children, at their first appearance, covered by a da brown, or even black, woolly covering. It is only after t has been shed, that the permanent fair hair, which child inherits from its parents, makes its appearan Occasionally the dark hair is retained for several wee

even months, after birth. This remarkable woolly vering can only be explained as an inheritance from our imordial long-haired ancestors, the Apes.

It is equally worthy of note that many of the higher pes resemble Man in the thin coat of hair which covers rtain parts of their body. In most Apes, especially in he higher Catarhines, the face is nearly or even quite bare, r is covered with hairs as thin and as short as those of Man. In these Apes also, just as in Man, the hair on the ack of the head is usually distinguished by its length, nd the males often have much beard and whisker. (Cf. ig. 202, p. 175). In both cases this masculine adornment as been acquired in consequence of sexual selection. n some Apes the breast and the inner sides of the joints re very thinly covered with hair—far less abundantly than s the back and the outer sides of the joints. On the other and, we not unfrequently see the shoulders, the back, and he outer sides of the limbs thickly covered with hair in nen of Indo-Germanic or Semitic race. It is a well-known act that in some families abundant hair on the body is ereditary, as is the relative vigour and character of the air-growth of the beard and head. These great differences n the total and partial hairiness of the body, which appear ery striking not only when we compare different races of nan, but even when we compare many families belonging o the same race, are very simply explained by the fact hat the entire hairy covering of Man is a rudimentary rgan, an unused inheritance, which has been transmitted rom the more hirsute Apes. In this matter, Man resembles he Elephant, Rhinoceros, Hippopotamus, Whale, and other Mammals of various orders which have also entirely or

partially lost their original coat of hair in consequence of adaptation.[168]

The form of Adaptation which has degraded the growth of hair on most parts of the human body, while preserving it, or even greatly developing it, on certain parts, was, in all probability, sexual selection. As Darwin has very clearly shown in his work on "The Descent of Man," sexual selection has had especially great influence in this respect. In consequence of the male Anthropoid Apes, in selecting a partner, preferring those females which were least hairy, and in consequence of the females preferring those suitors which were distinguished by peculiarly fine beard or head-hair, the general hirsuteness of the body was gradually degraded, while the beard and the hair of the head were advanced to a higher degree of perfection. Climatic conditions, and other circumstances unknown to us, may, however, also have promoted the loss of the hairy coat.

In proof of the assertion that the hairy covering of Man is directly inherited from the Anthropoid Apes, we find, according to Darwin, a curious evidence in the direction, otherwise inexplicable, in which the rudimentary hairs lie on our arms. Both on the upper and on the lower arm the hairs are directed towards the elbow, where they meet at an obtuse angle. Except in Man, this striking arrangement occurs only in the Anthropoid Apes, the Gorilla, Chimpanzee, Orang, and several species of Gibbons. In other Gibbons the hairs of both the lower and the upper arm are directed towards the hand, as in other Mammals. This remarkable peculiarity of Anthropoids and of Man can only be explained on the assumption that our common ape-like ancestors were accustomed, as they are even now,

during rain, to bring their hands together over their heads, or over a branch overhanging their heads. The reverse direction of the hairs, when the arms were in this position caused the rain to run off. Thus, even yet, the direction of the hairs on our lower arm testifies to this advantageous habit of our Ape-ancestors.

If the skin and its appendages are minutely examined, Comparative Anatomy and Ontogeny supply many similar important "records of creation," showing that they are directly inherited from the skin-covering of the Ape. We obtained our skin and hair by inheritance, immediately from Anthropoid Apes, these from the lower Apes, which, in turn, inherited the same parts from lower Mammals. This is also true of the other great organ-system which is developed from the skin-sensory layer—of the nervous system and the sensory organs. This very highly developed organ system, which performs the highest vital functions—those of the mind—we have inherited immediately from the Apes, and mediately from Mammals of a lower order.

The human nervous system, like that of all other Mammals, is, in its developed condition, a very complex apparatus, the anatomical arrangement and the physiological activity of which may, in general terms, be compared to a telegraph system. The central marrow (*medulla*), or central nervous system, represents the principal station, the innumerable "ganglion cells" (Fig. 7, vol. i. p. 129) of which are connected with each other and with numerous very delicate conducting lines by their branched processes. The latter are the peripheric "nerve fibres," distributed over the whole surface of the body; these, together with their terminal apparatus, the sense-organs, etc., constitute the "conductive

marrow," the peripheric nerve-system. Some, as se nerve-fibres, convey the sensations of the skin and of sense-organs to the central medulla; others, as motor ı fibres, transmit the impulses from the central marrow muscles.

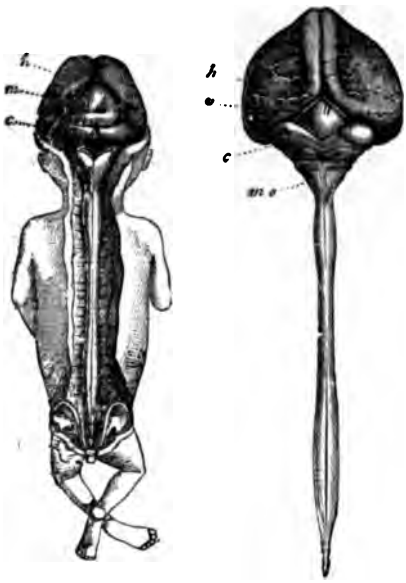


FIG. 217.—Human of three months, in size, seen from the dors the brain and dorsal ı exposed (after Koellik hemispheres of the ce (fore-brain); *m*, "four (mid-brain); *c*, small (hind-brain, or *cerel* Below the latter ; three-cornered "neck-m (after-brain).

FIG. 218.—Central ı of a human embryo months, in natural siz from the dorsal side Koelliker): *h*, large spheres; *v*, "four-bull small brain; *mo*, neck-m Below this the dorsal ı (marrow).

The central nervous system, or central marrow (*me centralis*), is the actual organ of mental activities, i stricter sense. Whatever view is taken of the int connection between this organ and its functions, it least, certain that those of its special activities whi call sensation, volition, and thought, are in man, as the higher animals, inseparably connected with the n development of this material organ. Hence we must ı sarily take a deep interest in the history of the develo

of this organ. As it alone can give us the most important information as to the nature of our "mind," it commands our most earnest attention. For if the central marrow develops in the human embryo exactly as in the embryos of all other Mammals, then the development of the human mental organ from the same central organ of other Mammals and, more remotely, from that of lower Vertebrates, cannot be questioned. It is, therefore, impossible to dispute the enormous significance of these phenomena of development.

In order to appreciate these rightly, a few words must first be said as to the general form and anatomical construction of the developed central marrow in Man. Like the central nervous system of all other Skulled Animals (*Craniota*), it consists of two distinct parts: firstly, of the brain or the medulla of the head (*encephalon*, or *medulla capitis*), and, secondly, of the spinal marrow (*medulla spinalis*). The former is enclosed in the bony skull, or "brain case," the latter in the bony vertebral canal, which is composed of a consecutive series of vertebræ, shaped like signet rings. (Cf. Plate V. Fig. 16, *m.*) From the brain proceed twelve pairs of head nerves, from the spinal marrow thirty-one pairs of medullary or spinal nerves for the remainder of the body. The spinal marrow, when examined merely anatomically, appears as a cylindrical cord with a spindle-shaped swelling in the region of the neck (at the last of the neck-vertebræ) and another in the lumbar region (at the first lumbar vertebra, Figs. 217, 218). At the swelling at the throat the large nerves of the upper limbs pass off from the spinal marrow, and those of the lower limbs from the swelling in the lumbar region. The upper end of the spinal marrow passes through the neck-marrow (*medulla oblon-*

gata) into the brain. The spinal marrow appears indeed to be a dense mass of nervous substance; but along its axis passes a very narrow canal, which is continued in front into the larger cavities of the brain, and which, like those cavities, is filled with a clear fluid.

The brain forms a considerable mass of nervous substance, of very complex, minute structure, which occupies

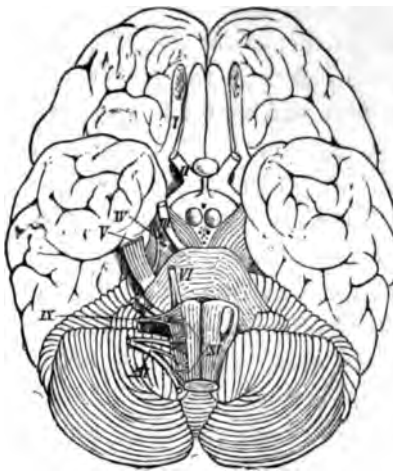


Fig. 219.—Human brain, seen from the lower side. (After H. Meyer.) Above (in front) is the large brain (*cerebrum*), with extensively branched furrows; below (behind) is the small brain (*cerebellum*), with narrow parallel furrows. The Roman numbers indicate the roots of the twelve pairs of brain nerves in order from front to back.

the greater part of the skull-cavity; it is roughly distinguishable into two main parts—the large and small brain (*cerebrum* and *cerebellum*). The former is situated in front and over the latter, and its surface exhibits the well-known characteristic convolutions and furrows (Figs. 219, 220). On its upper surface it is divided by a deep longitudinal slit into two lateral halves, the so-called "great hemispheres," which are connected by means of a bridge, or "cross-piece" (*corpus callosum*). A deep transverse fissure separates the large brain (*cerebrum*) from the small brain

bellum). The latter is situated more posteriorly and riorly, and shows on its outer surface equally numerous ows, which are, however, much finer and more regular,

ig. 220.—Human brain, seen from the left side. (After H. Meyer.) The ws of the large brain are indicated by large, thick lines, those of the brain by finer lines. Below the latter the neck-marrow is visible. f^1–f^3, al convolutions; *Ce. a Ce. p*, central convolutions; *R*, fissure of Rolan- *S*, Sylvian fissure; *T*, temporal or parallel fissure; *Pa*, parietal lobe; *An*, nnectant convolutions; *PO*, parieto-occipital fissure; *Su*, supra-marginal lution; *IP*, intra-parietal fissure; *t*, temporo-sphenoidal convolution.

between them are curved ridges (Fig. 219, lower part). small brain is also divided into two lateral halves by a itudinal furrow; these are the "small hemispheres," ch are connected at the top by a worm-like cross-piece, "brain-worm" (*vermis*), and at the bottom by a bridge *s varolii;* Fig. 219, VI.).

Comparative Anatomy and Ontogeny show, however, that Man, as in all other Skulled Animals, the brain originally ists not of two but of five distinct parts lying one nd another. These originally appear in the embryo of all

Skulled Animals (*Craniota*), from the Cyclostomi and Fishes up to Man, in exactly the same form, as five bladders placed one behind the other. Alike in their first rudiments, they, however, differ in their further development. In Man and all higher Mammals the first of these five bladders, the fore-brain, develops so excessively that, when mature, it forms, both in size and weight, by far the greater part of the whole brain. To it belong, not only the great hemispheres, but also the bridge (*corpus callosum*), which connects these two, the olfactory lobes, from which proceed the nerves of smell, and most of the processes lying on the roof and floor of the great lateral cavities of the two hemispheres; such, for instance, as the large streaked bodies (*corpora striata*). On the other hand, the "centres of sight," which lie between the streaked bodies, belong to the second main part, which develops from the twixt-brain; and to the same part belong the third brain ventricle (which is single) and the processes known as the "funnel" (*infundibulum*), the gray mass, and the "cone" (*conarium*). Behind these, and between the large brain and the small brain, we find a little mass, composed of two pairs of bosses, and called the "four bulbs," on account of two superficial furrows which cross each other at right angles, thus quartering the whole mass (Figs. 217, *m*, 218, *v*). Though these "four bulbs" are very insignificant in Man and the higher Mammalia, they constitute a distinct part of the brain, the third, or mid-brain, which is, on the contrary, especially well developed in the lower Vertebrates. The next or fourth part of the brain is the hind-brain, or small brain (*cerebellum*), in the strict sense of the term, with its single middle process, the "worm" (*vermis*), and its two lateral parts, the "small

emispheres" (Figs. 217, *c*, 218, *c*). Behind this comes, finally, he fifth and last part, the "neck-marrow" (*medulla oblon-ata*, Fig. 218, *mo*), which includes the single fourth brain entricle and the adjoining processes (pyramids, olives, and estiform bodies). The neck medulla passes directly down nto the spinal marrow. The narrow central canal of the pinal marrow extends into the wider "fourth ventricle" of he neck medulla, which is rhomboidal in shape, and the loor of which forms the "rhomboid groove." From this roceeds a narrow duct, called the "aqueduct of Sylvius," hich leads through the "four-bulbs" into the third ven-ricle, situated between the two "centres of sight;" and his cavity in turn is connected with the pair of lateral avities which lie right and left in the large hemispheres. ll the cavities of the central marrow are, therefore, directly onnected together. Individually all these parts of the brain hich we have enumerated have an infinitely complex, inute structure, which we cannot now study, and which ardly bears on our subject. This wonderful brain-struc-ure, as it occurs only in Man and the higher Vertebrates, is f the highest importance, simply because, in all Skulled nimals (*Craniota*), it develops from the same simple rudi-nents, from the five brain-bladders already enumerated. Cf. Plates VI. and VII.)

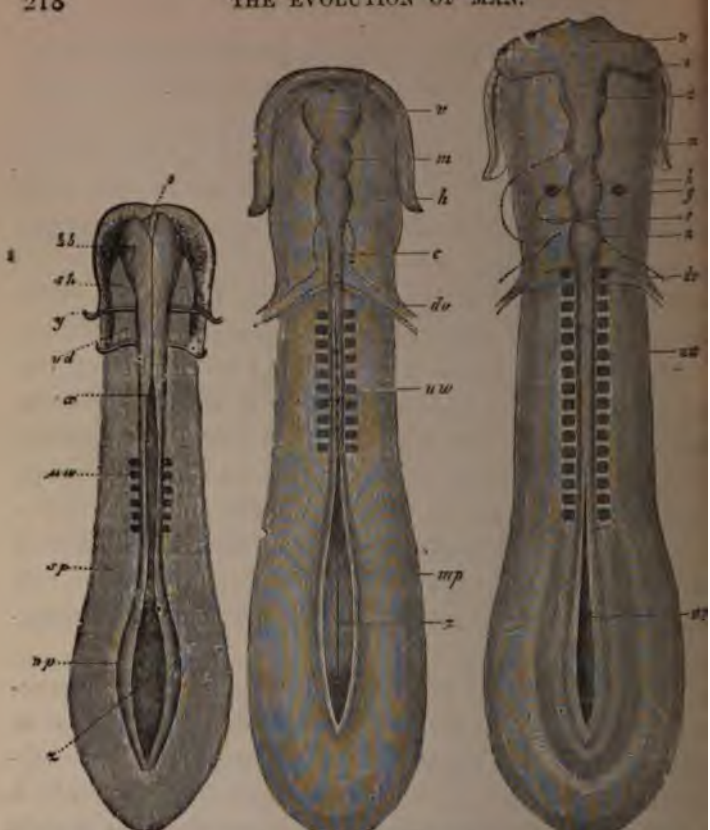
Before we direct our attention to the individual develop-nent of the complex brain from this series of simple ladders, we will, in order to understand the matter more learly, glance for a moment at those lower animals which ave no such brain. Even in the skull-less Vertebrates, in he Amphioxus, there is no real brain. In this case the hole central marrow is merely a simple cylindrical cord

traversing the body longitudinally, and terminating in front almost as simply as at the other end: it is a simple medullary tube (Plate XI. Fig. 15, *m*). We found, however, that the rudiment of the same simple medullary tube occurs in the ascidian larva (Plate X. Fig. 5, *m*) and in the same characteristic position, above the notochord. Moreover, when closely examined a small bladder-like swelling may be seen at the fore end of the medullary tube in these two closely allied animals; this is the first indication of a separation of the medullary tube into brain (m_1) and spinal marrow (m_2). When, however, we consider the undeniable relationship of the Ascidia to the rest of the Worms, it is evident that the simple central marrow of the former exactly answers to the simple nerve-ganglion which, in the lower Worms lies above the throat (*pharynx*), and which has, therefore, long been called the "upper throat ganglion" (*ganglion pharyngeum superius*). In the Gliding Worms (*Turbellaria*) the whole nerve system consists merely of this simple ganglion, which is situated on the dorsal side of the body, and from which nerve-threads radiate to the different parts of the body (Fig. 211, *gn*). This upper throat ganglion of the lower Worms is evidently the rudiment from which the more complex central marrow of the higher animals has developed. An elongation of the upper throat ganglion along the dorsal side gave rise to the medullary tube, which is characteristic of Vertebrates and the young forms of Ascidia alone. On the other hand, in all other animals, the central nerve system has developed in a very different manner from the upper throat ganglion; in Articulated Animals (*Arthropoda*) especially, the latter has developed into a throat (pharyngeal) ring, with a ventral marrow; this is the case, also, in the articu-

ed Ringed Worms (*Annelida*) and the Star-animals (*Echi-derma*), which originated from Arthropods. The Soft-lied Animals (*Mollusca*) also have a throat ring, which is ite unrepresented in Vertebrates. Only in Vertebrates central marrow developed along the dorsal side, while all other animals which have been named it developed ng the ventral side of the body.[169]

Descending below the Worms we find very many mals which are entirely without a nerve-system, and in ich the functions of that system are performed simply by outer skin-covering—by the cells of the skin-layer, or derm. This is the case in many low Plant Animals *ophyta*), for instance, in all Sponges, and in the common h-water Polyp, the Hydra. It was also undoubtedly the in all extinct Gastræads. In all Primitive Animals *otozoa*) the nerve-system is, of course, unrepresented, for e have not as yet attained to the development of germ-rs.

In considering the individual development of the nerve-tem in the human embryo, we must first of all start from important fact already mentioned, that the first rudi-nt of the system is the simple medullary tube, which aches itself from the outer germ-layer along the middle of the lyre-shaped primitive germ. We found (Figs. 87, vol. i. p. 298) that the rectilineal primitive groove, or sal furrow, first arises in the centre of the lyre-shaped m-disc. On each side of this rise the two parallel dorsal medullary swellings. The free margins of these bend to-ds each other, coalesce, and form the closed medullary tube gs. 88–93, vol. i. pp. 300–309). At first this tube lies directly er the horn-plate; it is, however, afterwards situate



FIGS. 221–223.—Lyre-shaped (or sole-shaped) germ-shield of a Chick, i three consecutive stages of evolution, seen from the dorsal surface: abou twenty times enlarged. Fig. 221, with six pairs of primitive vertebra The brain a simple bladder (*hb*). The medullary furrow is wide open fro the point *x*, very wide at *z*. *mp*, Marrow (or medullary) plates; *sp*, side plates; *y*, boundary between the throat cavity (*sh*) and the head-intesti (*vd*). Fig. 222, with ten pairs of primitive vertebræ. The brain consists three bladders: *v*, fore-brain; *m*, mid-brain; *h*, hind-brain. *c*, Heart; d yelk-veins. The medullary furrow is wide open behind (*z*). *mp*, Marro plates. Fig. 223, with sixteen pairs of primitive vertebræ. The bra consists of five bladders: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; hind-brain; *n*, after-brain. *a*, Eye-vesicles; *g*, ear-vesicles; *c*, heart; *yelk-veins*; *mp*, marrow-plate. *uw*, primitive vertebræ.

ite internally, the upper edges of the primitive vertebral ates, which penetrate, from right and left, in between the rn-plate and the medullary tube, uniting above the latter, d thus completely embedding it in a closed canal. As genbaur most aptly remarks, "This gradual embedding the interior of the body must be regarded as an incident quired in connection with progressive differentiation, and th the consequent higher capacity, by which the most portant organ of the system is secured in its interior."

To every thoughtful and unprejudiced man it must pear an extremely important and pregnant fact, that our ntal organ, like that of all other Skulled Animals (*Cra-ota*), commences in the same way and in exactly the same nple form in which this organ remains for life in the vest Vertebrate, the Amphioxus (vol. i. p. 420, Fig. 151; ate XI. Fig. 15, *m*). In the Cyclostomi, that is, in the stage ove the Acrania, the anterior extremity of the cylindrical dullary tube begins to extend, at an early period, in the m of a pear-shaped bladder, which is the first distinct liment of a brain (Plate XI. Fig. 16, m_1). For the central dulla of Vertebrates thus first distinctly differentiates o its two main sections, the brain (m_1) and the spinal rrow (m_2). The first faint indication of this important ferentiation is discoverable in the Amphioxus, perhaps en in the Ascidian larva (Plate X. Fig. 5).

The simple bladder-like form of the brain, which is ained for a considerable time in the Cyclostomi, also pears at first in all higher Vertebrates (Fig. 221, *hb*). In latter, however, it soon disappears, in consequence of separation of the simple brain-bladder, by transverse ntractions of its circumference, into several consecutive

parts. Two of these contractions first appear, and sequently the brain forms three consecutive bladders (

FIGS. 224–226.—Central row of human embryo in seventh week, two cm. (After Koelliker.) Fig. view of the whole embryo the dorsal side; the brai dorsal marrow laid bare. 225, the brain and upper of the dorsal marrow fro left side. Fig. 224, the brain from above: *v*, fore-brain; *z*, twixt-l *m*, mid-brain; *h*, hind-brain; *n*, after-brain.

222, *v*, *m*, *h*). The first and third of these three prim bladders then again separate by transverse contract each into two parts, and thus five consecutive bladder divisions are formed (Fig. 223: cf. also Plate V. 13–16; Plates VI. and VII., second cross-line). These fundamental brain-bladders, which re-occur in the same in the embryos of all the Skulled Animals (*Craniota*), first clearly recognized by Baer, who understood their importance and distinguished them, according to their tive positions, by very appropriate names, which are st general use: I., fore-brain (*v*); II., twixt-brain (*z*); III., brain (*m*); IV., hind-brain (*h*); and V., after-brain (*n*).

In all Skulled Animals, from the Cyclostomi to the same parts, although in very various forms, de from these five original brain-bladders. The first bla the fore-brain (*protopsyche*, *v*), forms by far the largest of the so-called "great brain" (*cerebrum*); it forms the great hemispheres, the olfactory lobes, the streaked b (*corpora striata*), and the cross-piece (*corpus callos* together with the "arch" (*fornix*). From the se

adder, the twixt-brain (*deutopsyche, z,*) proceed primarily e "centres of sight" and the other parts which surround e so-called "third brain-ventricle," also the "funnel" *nfundibulum*), the "cone" (*conarium*), etc. The third adder, the mid-brain (*mesopsyche, m*), furnishes the small roup of the "four bulbs," together with the "aqueduct of ylvius." From the fourth bladder, the hind-brain (*meta-ysche, h*), the greater part of the so-called "little brain" *erebellum*) develops; the central "worm" (*vermis*), and e two lateral "small hemispheres." The fifth bladder, nally, the after-brain (*epipsyche, n*), forms the neck-arrow, or the "elongated marrow" (*medulla oblongata*), gether with the rhomboid groove, the pyramids, olives, etc.

The very highest importance must certainly be ascribed the fact, seen in Comparative Anatomy and Ontogeny, at the brain is originally formed in exactly the same way the embryos of all Skulled Animals (*Craniota*), from the west Cyclostomi and Fishes, to Apes and Man. In all, e first rudiment of the brain is a simple bladder-like pansion at the anterior extremity of the medullary tube. all, the five bladders are formed from this simple bladder-ke expansion, and in all, these five primitive brain-adders develop into the permanent brain, with its many mplex anatomical arrangements, which afterwards appear such extremely diverse forms in the various vertebrate asses. On comparing the mature brain of a Fish, an mphibian, a Reptile, a Bird, and a Mammal, it is hardly nceivable that the several parts of these forms, so ex-emely different, both internally and externally, may be aced back to one common condition. And yet, all these rious brains of Craniota have originated from exactly the

same rudimentary form. We need only compare the embryos of these various classes of animals at corresponding stages of development, in order to assure ourselves of this fundamental fact. (Cf. Plates VI. and VII., second cross-line.)

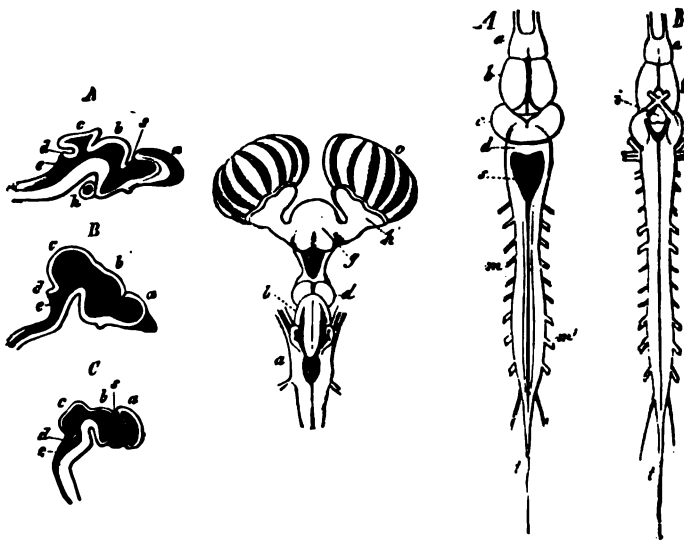


FIG. 227.—Brains of three embryonic Skulled Animals in vertical longitudinal sections: *A*, of a Shark (*Heptanchus*); *B*, of a Snake (*Coluber*); *C*, of a Goat (*Capra*); *a*, fore-brain; *b*, twixt-brain; *c*, mid-brain; *d*, hind-brain; *e*, after-brain; *s*, primitive fissure of the brain. (After Gegenbaur.)

FIG. 228.—Brain of a Shark (*Scyllium*) from the dorsal side: *g*, fore-brain; *h*, olfactory bulbs of the fore-brain, which send the large olfactory nerves to the large nose capsules (*o*); *d*, twixt-brain; *b*, mid-brain (behind it, the insignificant rudiment of the hind-brain); *a*, after-brain. (After Busch.)

FIG. 229.—Brain and dorsal marrow of a Frog: *A*, from the dorsal side; *B*, from the ventral side; *a*, olfactory bulbs, in front of the fore-brain (*b*); *i*, funnel at the base of the twixt-brain; *c*, mid-brain; *d*, hind-brain; *s*, rhomboid groove in the after-brain; *m*, dorsal marrow (very short in the frog); *m'*, root-processes of the spinal nerves; *t*, fibre at the end of the dorsal marrow. (After Gegenbaur.)

A thorough comparison of the corresponding stages of evelopment in the brain in the various Skulled Animals *raniota*) is very instructive. If it is applied to the whole ries of skulled classes, the following extremely interest-g facts soon become evident: in the Cyclostomi (*Myxi-oides* and *Petromyzontes*), which, as we have seen, are e lowest and earliest Skulled Animals, the whole brain mains for life at a very low and primitive stage of evelopment, through which the embryos of the other kulled Animals pass very rapidly; the five original ctions of the brain are visible throughout life in an almost nmodified form. But even in Fishes, an essential and nportant transformation of the five bladders takes place; is evidently from the brain of the Primitive Fishes Selachii; Fig. 228), that, on the one side, the brain of the ther Fishes, and on the other, the brain of the Amphibians nd also of the higher Vertebrates, must be traced. In ishes and Amphibians (Fig. 229), the central part, the id-brain, and also the fifth section, the after-brain, are pecially developed, while the first, second, and fourth ctions remain far behind. In the higher Vertebrates, the xact reverse is the case, for in these the first and fourth ctions, the fore and hind brains, develop pre-eminently; on e other hand, the mid-brain remains very small, and the fter-brain is also much smaller. The greater part of the four-bulbs" is covered by the large brain (*cerebrum*) and e after-brain by the small brain (*cerebellum*). Even mong the higher Vertebrates themselves, numerous grada-ons occur in the structure of the brain. From the Am-hibians upward, the brain, and with it the mental life, evelops in two different directions, of which the one is

carried out in Reptiles and Birds, the other in Mamm
The latter are especially distinguished by the very cha
teristic development of the first section, the fore-brain.

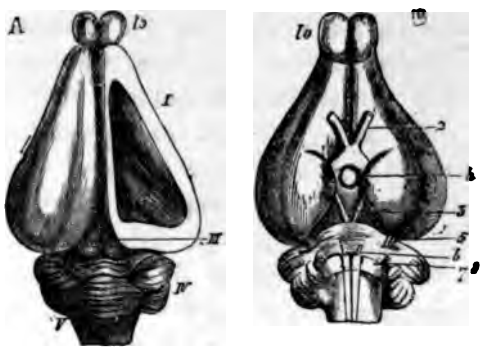


FIG. 230.—Brain of Rabbit: *A*, from the dorsal side; *B*, fro
ventral side; *lo*, olfactory lobules; I., fore-brain; *h*, hypophysis at th
of the twixt-brain; III., mid-brain; IV., hind-brain; V., after-brain; 2
nerve; 3, motor nerve of the eye; 5–8, fifth to eighth nerves of the
In *A*, the upper surface of the right large hemisphere (I.) is remov
that the streaked bodies (*corpora striata*) can be seen in its side ch
(*ventriculus lateralis*). (After Gegenbaur.)

Mammals alone (Fig. 230) does this "great brain" de
to such an extent, that it eventually covers all the
parts of the brain from above.

There are also remarkable differences in the rel
positions of the brain-bladders. In the lower Sk
Animals the five brain-bladders are at first situated
behind the other in the same plane. If the brain i
garded from the side, a straight line may be drawn thr
all the five bladders. But in the three higher verte
classes, in the Amnion Animals (*Amniota*), a notic
curving of the rudimentary brain takes place, simultane

ith the head and neck curving of the whole body, owing the fact that the whole upper dorsal surface of the brain rows much faster than the lower ventral surface. The esult is that the brain is so curved that its parts are afterards situated thus: the fore-brain lies quite in front and elow, the twixt-brain somewhat higher and over it, while he mid-brain lies highest of all and projects furthest forward; the hind-brain is situated lower, the after-brain yet urther back and below. This disposition occurs only in he three classes of the Amniota, in Reptiles, Birds, and Iammals. (Cf. Plates I., VI., and VII.)

Though, in general features of growth, the brains of Iammals correspond with those of Birds and Reptiles, yet triking differences very soon appear between the two. n Birds and Reptiles (Plate VI. Figs. *H* and *C*), the midrain (*m*) and the central part of the hind-brain develop onsiderably. In Mammals, on the other hand, these parts emain small, and instead, the fore-brain begins to grow o rapidly that it covers the other bladders from in front nd above. As it constantly grows further back, it evenually covers the whole of the rest of the brain above, nd also encloses the central part from the sides. This rocess is of the greatest importance, because this fore-brain s the organ of the higher mental activities,—because in it re accomplished those functions of the nerve-cells, the sum f which is generally designated as the mind, or the "spirit" n the narrower sense. The highest activities of the animal ody, the wonderful manifestations of consciousness, the omplex phenomena of the activities of thought, have their eat in the fore-brain. It is possible to remove the great emispheres of a Mammal, piece by piece, without killing

the animal, thus proving that the higher mental activities, consciousness and thought, conscious volition and sensation, may be destroyed one by one, and finally entirely annihilated. If the animal thus treated is artificially fed, it may be kept alive for a long time; for the nourishment of the entire body, digestion, respiration, the circulation of the blood, secretion, in short, the vegetative functions, are in no way destroyed by this destruction of the most important mental organs. Conscious sensation and voluntary motion, the capacity for thought and the combination of the various higher mental activities, have alone been lost.

This fore-brain, the source of all these most wonderful nervous activities, reaches that high degree of perfection only in the higher Placental Animals (*Placentalia*); a fact which explains very clearly why the higher Mammals so far excel the lower in intellectual capacity. While the "mind" of the lower Placental Animals does not exceed that of Birds and Reptiles, we find among the higher Placentalia an uninterrupted gradation up to Apes and Man. Accordingly, their anterior brains show surprising differences in the degree of perfection. In the lower Mammals, the surface of the great hemispheres (the most important part) is entirely smooth and even. The fore-brain, too, remains so small that it does not even cover the mid-brain above (Fig. 230). One stage higher, and this latter is indeed entirely covered by the excessive growth of the fore-brain; but the hind-brain remains free and uncovered. At last, in Apes and in Man, the fore-brain covers the hind-brain also. A similar gradual advance may also be traced in the development of the peculiar furrows and protuberances which are so characteristically prominent on the surface of the large brain

(*cerebrum*) of higher Mammals (Figs. 219, 220). If the brains of the various mammalian groups are compared with reference to these convolutions and furrows, it appears that their gradual development is entirely proportionate with the development of the higher intellectual activities. Much attention has recently been devoted to this particular branch of the Anatomy of the brain, and very striking individual differences have been found even within the human race. In all human individuals distinguished by peculiar ability and great intellect, these swellings and furrows on the surface of the great hemispheres exhibit a much greater development than in common average men; while in the latter, again, they are more developed than in Cretins and others of unusually feeble intellect. There are also similar gradations in the internal structure of the fore-brain in Mammals. The great cross-piece (*corpus callosum*), especially, the bridge between the two great hemispheres, is developed only in Placental Animals. Other arrangements, for example, in the structure of the lateral cavities, which seem primarily to be peculiar to Men as such, reappear only in the higher species of Apes. It was long believed that Man had some entirely peculiar organs in the great brain (*cerebrum*), which are wanting in all other animals. But close comparison has shown that this is not the case, but that rather the characteristic qualities of the human brain exist in a rudimentary state even in the lower Apes, and are developed to a greater or less degree in the higher Apes. Huxley, in his important and much-quoted book, "Evidence as to Man's Place in Nature" (1863), has shown, most convincingly, that within the Ape-series the differences in the formation of the brain are greater between the

higher and lower Apes than between the higher Apes and Man. This statement is, indeed, equally true of all the other parts of the body. But the fact that it is true of the central marrow is especially important. This does not become fully evident unless these morphological facts are considered in connection with the corresponding physiological phenomena; until we consider that every mental activity requires for its complete and normal exercise the complete and normal condition of the corresponding brain-structure. The extremely complex and perfect active phenomena within the nerve-cells, summed up in the word "mental life," can no more exist without their organs in the vertebrates, including man, than can the circulation of the blood without a heart or blood. As, however, the central marrow of Man has developed from the same medullary tube as in all other Vertebrates, so also must the mental life of Man have had the same origin.

All this is of course true of the conductive marrow, or the so-called "peripheric nervous system." This consists of the *sensitive* nervous fibres which convey the impressions of sensation from the skin and the organs of the senses in a centripetal direction to the central marrow; as well as of the *motor* nervous fibres, which, reversely, convey the movements of volition from the central marrow, in a centrifugal direction to the muscles. By far the greater part of these peripheric conductive nerves originates from the skin-fibrous layer, by peculiar local differentiation of the rows of cells into the respective organs.

The membranous coverings and blood-vessels of the central marrow are identical in origin with the greater part of the conductive marrow; these membranous coverings

are the inner membrane (*pia mater*), the central membrane (*meninx arachnoides*), and the outer membrane (*dura mater*). All these parts are developed from the skin-fibrous layer.

TABLE XXVII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN SKIN-COVERINGS.

I. *First Period: Skin of Gastræads.*

The entire skin-covering (including the nervous system, not yet differentiated from it) consists of one simple layer of ciliated cells (exoderm, or primary skin-layer); as it is at the present day in the gastrula of the Amphioxus.

II. *Second Period: Skin of Primitive Worms.*

The simple exoderm of the Gastræad has thickened and split into two distinct layers, or secondary germ-layers: the skin-sensory layer (rudiment of the horn-plate and nerve-system) and the skin-fibrous layer (rudiment of the leather skin (*corium*), the muscle-plate and the skeleton-plate. The skin is potentially both covering and mind.

III. *Third Period: Skin of Chordonia.*

The skin-sensory layer has differentiated into the horn-plate (*epidermis*), and the central marrow (upper throat ganglia) separated from it; the latter elongates into a medullary tube. The skin-fibrous layer has differentiated into the leather plate (*corium*) and, below this, the skin-muscular pouch (as in all Worms).

IV. *Fourth Period: Skin of Acrania.*

The horn-plate yet forms a simple epidermis. The leather-plate is fully differentiated from the muscle and skeleton plates.

V. *Fifth Period: Skin of Cyclostoma.*

The outer-skin remains a simple, soft mucous layer of cells, but forms one-celled glands (cup-cells). The leather-skin (*corium*) differentiates into *cutis* and *sub-cutis*.

VI. *Sixth Period: Skin of Primitive Fishes.*

The outer skin is still simple. The leather skin forms placoid scales or small bony tablets, as in the Selachii.

VII. *Seventh Period: Skin of Amphibia.*

The outer skin differentiates into an outer horn-layer, and an inner mucous layer. The ends of the toes are covered with horny sheaths (first rudiments of claws or nails).

VIII. *Eighth Period: Skin of Mammals.*

The outer skin forms the appendages characteristic of Mammals only; hair, and sebaceous, sweat, and milk glands.

TABLE XXVIII.

Systematic Survey of the most important Periods in the Phylogeny of the Human Nervous System.

I. *First Period: Medulla of Gastræads.*

The nerve system is not yet distinct from the skin, and, together with the latter, is represented by the simple cell-stratum of the exoderm, or primary skin-layer; as it is at the present day in the gastrula of the Amphioxus.

II. *Second Period: Medulla of Primitive Worms.*

The central nerve system is yet, at first, a part of the skin-sensory layer, and afterwards consists of a throat medulla, a simple nerve-ganglion lying above the throat; as it is now in the lower Worms: the upper throat-ganglion.

III. *Third Period: Medulla of Chordonia.*

e central nerve system consists of a simple medullary tube, an tion of the upper throat ganglion, which is separated from the intes- r a notochord (*chorda dorsalis*).

IV. *Fourth Period: Medulla of Acrania.*

e simple medullary tube differentiates into two parts: a head, and a part. The head medulla resembles a small, pear-shaped, simple g (the primitive brain, or first rudiment of the brain) on the anterior ity of the long cylindrical spinal marrow.

V. *Fifth Period: Medulla of Cyclostoma.*

e simple, bladder-like rudiment of the brain divides into five con- e brain-bladders of simple structure.

VI. *Sixth Period: Medulla of Primitive Fishes.*

e five brain-bladders differentiate into a form similar to that now nently retained by the Selachii.

VII. *Seventh Period: Medulla of Amphibia.*

e differentiation of the five brain-bladders progresses to that structure is now characteristic of the brain in Amphibia.

VIII. *Eighth Period: Medulla of Mammals.*

e brain attains the characteristic peculiarities distinctive of Mammals. llowing may be distinguished as subordinate stages of development; brain of Monotremes; 2, the brain of Marsupials; 3, the brain of pes; 4, the brain of Apes; 5, the brain of Man-like Apes; 6, the of Ape-men; and 7, the brain of Man.

TABLE XXIX.

Systematic Survey of the Evolution of the Skin-covering and Nerve System.

XXIX. *A.* Survey of the Evolution of the Skin-covering.

Skin (*Derma*, or *Integumentum*)	Outer-skin (*Epidermis*) Product of the Skin-sensory-layer	Horn-layer of the outer skin (*Stratum corneum*)	Hair
			Nails
		Mucous layer of the outer skin (*Stratum mucosum*)	Sweat glands
			Tear glands
			Sebaceous glands
			Milk glands
	Leather-skin (*Corium*) Product of the Skin-fibrous-layer	Fibrous layer of the leather skin (*Cutis*)	Connective tissue
			Fatty tissue
			Muscular tissue
			Blood-vessels
		Fatty layer of the leather skin (*Subcutis*)	Papillæ of taste and nerves of the leather skin

XXIX. *B.* Survey of the Evolution of the Central Marrow.

Central Marrow, or **Central Nerve System** (*Psyche*, or *Medulla Centralis*). Product of the **Skin-sensory layer**	I. Fore-brain (*Protopsyche*)	Great hemispheres	*Hemisphæra cerebri*
		Olfactory lobules	*Lobi olfactorii*
		Lateral chambers	*Ventriculi laterales*
		Streaked bodies	*Corpora striata*
		Arch	*Fornix*
		Cross piece	*Corpus callosum*
	II. Twixt-brain (*Deutopsyche*)	Centre of sight	*Thalami optici*
		Third chamber of the brain	*Ventriculus tertius*
		Pineal body	*Conarium*
		Funnel	*Infundibulum*
	III. Mid-brain (*Mesopsyche*)	Four bulbs	*Corpus bigeminum*
		Aqueduct of Sylvius	*Aquæductus Sylvii*
		Brain stalks	*Pedunculi cerebri*
	IV. Hind-brain (*Metapsyche*)	Small hemispheres	*Hemisphæra cerebelli*
		Brain worm	*Vermis cerebelli*
		Brain bridge	*Pons Varolii*
	V. After-brain (*Epipsyche*)	Pyramids	*Corpora pyramidalia*
		Olives	*Corpora olivaria*
		Restiform bodies	*Corpora restiformia*
		Fourth chamber of the brain	*Ventriculus quartus*
	VI. Dorsal Marrow	*Notopsyche*	*Medulla spinalis*
Medullary coverings (*Meninges*)	Enveloping membranes, with the nutritive blood-vessels of the brain and spinal cord	1. Soft medullary skin	*Pia mater*
		2. Central medullary skin	*Arachnoidea*
		3. Hard medullary skin	*Dura mater*
		(Products of the skin-fibrous layer)	

CHAPTER XXI.

DEVELOPMENT OF THE SENSE-ORGANS.

Origin of the most highly Purposive Sense-organs by no Preconceived Purpose, but simply by Natural Selection.—The Six Sense-organs and the Seven Sense-functions.—All the Sense-organs originally Developed from the Outer Skin-covering (from the Skin-sensory Layer).—Organs of the Pressure Sense, the Heat Sense, the Sexual Sense, and the Taste Sense.—Structure of the Organ of Scent.—The Blind Nose-pits of Fishes.—The Nasal Furrows change into Nasal Canals.—Separation of the Cavities of the Nose and Mouth by the Palate Roof.—Structure of the Eye.—The Primary Eye Vesicles (Stalked Protuberances from the Twixt-brain).—Inversion of this Eye Vesicle by the Crystalline Lens, separated from the Horn-plate.—Inversion of the Vitreous Body.—The Vascular Capsule and the Fibrous Capsule of the Eyeball.—Eyelids.—Structure of the Ear.—The Apparatus for Perception of Sound: Labyrinth and Auditory Nerve.—Origin of the Labyrinth from the Primitive Ear Vesicles (by Separation from the Horn-plate).—Conducting Apparatus of Sound: Drum Cavity, Ear Bonelets, and Drum Membrane.—Origin of these from the First Gill-opening and the Parts immediately round it (the First and Second Gill-arch).—Rudimentary Outer Ear.—Rudimentary Muscles of the Ear-shell.

"Systematic Physiology is based especially upon the history of development, and unless this is more complete, can never make rapid progress; for the history of development furnishes the philosopher with the materials necessary for the secure construction of a system of organic life. Hence anatomical and physiological researches should be prosecuted more from the

point of view of development than is now the case; that is, we shou each organ, each tissue, and even each function simply with the determining *whence they have arisen*."—EMIL HUSCHKE (1832).

THE sense-organs are undeniably among the most imp and most interesting parts of the human body; t their activity alone we recognize the objects in the around us. "Nihil est in intellectu, quod non prius fu sensu." They are the true springs of our mental life. other part of the animal body can we point to such ext delicate and complex anatomical contrivances, co-op for a definite physiological aim; and in no other par body do these wonderful and very apt contrivances s first, to indicate a premeditated creative design so sively. Hence it is that, in accordance with the r teleological view, it has been customary to admire called "wisdom of the Creator" and the "purposi trivances of His Creation" especially in this matte on more mature consideration it will be observed t Creator, according to this conception, does after all l the part of an ingenious mechanic or of a skilful maker; just, indeed, as all these cherished tele conceptions of the Creator and His Creation are b childish anthropomorphism.

We admit that at first sight this teleological c tion seems to afford the simplest and fittest interp of these very apt contrivances. If the structure a tions of the very highly developed sense-organs a regarded, it seems as though their origin is hardly able except on the assumption of a supernatural act. But it is exactly on this point that the his

ion proves most clearly that this received conception cally false. The history of evolution convinces us that ghly purposive and admirably constituted sense organs, l other organs, have developed without premeditated that they originated by the same mechanical process tural Selection, by the same constant interaction aptation and Heredity, by which all the other pur- contrivances of the animal organization have been and gradually evolved during the "Struggle for nce."

ke most other Vertebrates, Man possesses six distinct of sense, which accomplish seven distinct sensations. xternal skin-covering accomplishes the sensation of re (resistance) and of temperature (warmth and cold). the earliest, the lowest, and the least differentiated of sense; it is distributed over the entire surface of dy. The other sensorial activities are localized. The sense is limited to the skin-covering of the external organs, just as the sense of taste is limited to the s membrane of the mouth-cavity (tongue and palate), e sense of smell to the mucous membrane of the avity. Special mechanical contrivances of great com- exist for the two highest and most differentiated of sense, the eye for the sense of sight, and the ear t of hearing.

mparative Anatomy and Physiology show that in the imals specialized sense-organs are entirely wanting, and l sensations are transmitted through the outer surface kin-covering. The undifferentiated skin-layer, or exo- of the Gastræa is the simple cell-layer from which the

differentiated sense-organs of all Intestin
and, therefore, of all Vertebrates, originall
ing from the consideration that necess
superficial parts of the body, those imm
the outer world, could have accompli
should be justified in conjecturing *à pri*
sense also owe their origin to the same p
the fact. The most important part
develops from the outermost germ-la
sensory layer; in part, directly from th
part, from the brain, the foremost sectio
tube, after this has separated from t
comparing the individual development o
of sense, we see that at first they make
the simplest conceivable form: only v
that wonderful perfect structure deve
higher sense-organs eventually become t
and the most complex mechanisms of
tion. All organs of sense are, howeve
portions of the external skin-covering
nerves are distributed. Even these ne
homogeneous and undifferentiated in cl
by division of labour, the various fu
energies" of the different sensorial nerv
taneously the simple terminal expan
nerves in the skin-covering developed
plex organs.

The important bearings of these h
just appreciation of mental life will
The whole philosophy of the future

Three Groups.	*Sense-organs.*	*Sense-nerves.*	*Sense-funct*
A. Sense-organs in which the terminal expansions of the nerves are distributed in the outer skin-covering.	I. Skin-covering (outer skin, or *epidermis*, and leather - skin, or *corium*)	I. Skin nerves (*nervi cutanei*)	Sense of pr Sense of wa
	II. External sexual parts (*penis and clitoris*)	II. Sexual nerves (*nervi pudendi*)	3. Sexual s
B. Sense-organs in which the terminal expansions of the nerves are distributed over inverted grooves of the outer skin-covering.	III. Mucous membrane of the mouth - cavity (tongue and palate)	III. Taste nerve (*nervus glossopharyngeus*)	4. Sense of
	IV. Mucous membrane of the nose-cavity	IV. Olfactory nerve (*n. olfactorius*)	5. Sense of
C. Sense-organs in which the terminal expansions of the nerves are distributed over vesicles separated from the external skin-covering.	V. Eye	V. Sight nerve (*n. opticus*)	6. Sense of
	VI. Ear	VI. Ear-nerve (*n. acousticus*)	7. Sense of ing

Of the developmental history of the lower orga sense I have but little to say. The development of the covering, which is the organ of the sense of pressure (of touch) and of warmth, we have already traced (p. I need only add that in the leather skin (*corium*) of as of all higher Vertebrates, innumerable microscopic s organs develop, the direct relations of which to the s tions of pressure or resistance, of warmth and of col not yet ascertained. These organs, in or upon whic sensitive skin-nerves terminate, are the so-called " bodies" and the "Pacinian bodies," named after thei

verer, Pacini. Similar bodies are also found in the organs the sexual sense, in the penis of the male and in the itoris of the female; these are processes of the integument, nd the development of which we shall consider presently, connection with that of the other organs of generation. he development of the organ of taste, the tongue and the alate, we will also consider presently, in connection with at of the intestinal canal, to which these parts belong. o one point, however, I will now call particular attention, iz., the mucous membrane of the tongue and palate, in hich the taste-nerve terminates, is also in its origin a portion f the external skin-covering. For, as we found, the entire outh-cavity originates, not as a part of the actual intes- nal canal, but as a groove-like inversion of the external kin (vol. i. p. 338). Its mucous membrane, therefore, is rmed, not from the intestinal layer, but from the skin- yer, and the taste-cells on the upper surface of the tongue nd palate arise, not from the intestinal-glandular layer, ut from the skin-sensory layer.

This is equally true of the mucous membrane of the rgan of smell, the nose. The history of the development f this sense-organ is, however, of far higher interest. lthough the human nose, externally viewed, seems simple nd single, yet in Man, as in all higher Vertebrates, it onsists of two perfectly distinct halves, of a right and a left asal cavity. These two cavities are entirely separated by vertical partition, so that the passage into the right nasal avity lies only through the right nostril, and into the left avity only through the left nostril. Posteriorly the two asal cavities open separately through the two posterior asal apertures into the head of the pharynx, so that the

pharynx may be entered without touching the cavity o mouth. This is the passage by which air is usually inh the mouth being shut, it enters the pharynx, and tl passes through the windpipe into the lungs. Both cavities are separated from the mouth-cavity by the zontal bony palate roof, to the back of which the palate and the uvula is attached, like a hanging cu In the upper and hinder portion of both nasal cavitie olfactory nerve extends over the mucous membrane, ' lines these parts. This is the first pair of brain n which issue from the skull-cavity through the sieve Its branches extend partly over the partition wall partly over the inner side-walls of the nasal caviti which are attached the "shells," or spongy bones (nose—complex bony structures. These "shells" are further developed in many of the higher Mammals in Man. In all Mammals there are three of these "s in each of the two nasal cavities. The sensation of is produced by a current of air, containing odori matters, passing over the mucous membrane of the ca and there coming in contact with nerve-ends.

The peculiar characters which distinguish the olf organ of Mammals from that of lower Vertebrat represented in Man. In all specific points the huma exactly resembles that of the Catarhine Apes, some of indeed possess an entirely human external nose (se of the Nose-ape, Fig. 202, p. 175). The first rudiment olfactory organ in the human embryo does not, ho show any signs of the fine form of the future cat nose. Indeed, it first appears in the same form persists for life in Fishes; in the form of two simpl

grooves in the skin of the upper surface of the head. In Fishes two of these mere blind nose-pits are found in upper surface of the head; sometimes they are situated the back, near the eyes, sometimes near the snout, or, ain, near the mouth-opening (Fig. 191, *n*, p. 113). They are ed by mucous membrane in folds, over which the end anches of the olfactory nerves spread.

In this its original condition the double nose of all nphirhina (p. 101) is entirely unconnected with the pri-tive mouth-cavity. The connection, however, begins to

FIG. 231.—Head of a Shark (*Scyl-n*), from the ventral side: *m*, mouth ning; *o*, nose grooves, or pits; *r*, al furrow; *n*, nose-flap in its ural position; *n'*, nose-flap turned (The dots are openings of mucous ts.) (After Gegenbaur.)

pear even in some Primitive Fishes (*Selachii*); a super-al skin-furrow extends on each side from the nose-groove wn to the adjacent corner of the mouth. This furrow, nasal channel, or furrow (Fig. 231, *r*), is of great sig-icance. In many Sharks (e.g., *Scyllium*) a special process the frontal skin, the nasal flap, or "inner nasal process," rlaps the nasal furrow (*n*, *n'*). Opposite to this the outer e of the furrow rises and forms the "outer nasal process." Dipneusta and Amphibia these two nasal processes meet r the furrow and coalesce, thus forming a canal, the asal canal." There is now a passage from the external al groove through this canal directly into the mouth-

cavity, which latter was developed independently
groove. In the Dipneusta and the lower Amphi
internal opening of the nasal canal lies well forward
the lips); in the higher Amphibia it lies further ba
the three highest vertebrate classes, the Amnio
primary mouth-cavity is separated by the formation
horizontal palate roof into two perfectly distinct
the superior (or secondary) nasal cavity, and the
(or secondary) mouth-cavity. The nasal cavity
separated by the vertical partition into two distinct
into a right and a left nasal cavity.

Comparative Anatomy thus still shows us simultan
in the ascending series of the double-nostrilled Vert
from Fishes up to Man, all the various stages of d
ment of the nose which the very highly developed o
organ of the higher Mammals has passed through
sively in the different periods of its tribal histor
first rudiment of the organ of smell in the embryo
and in that of all the higher Mammals, makes its app
in the same entirely simple form which is retained thr
life by the nose of Fishes. At a very early st
while no trace of the characteristic facial structure
is yet visible, a pair of small grooves appear on t
of the head, and before the primitive mouth-cavity
were first discovered by Baer, and by him properly
named "olfactory grooves" ("Riechgruben," Figs.
233, *n*). These primitive nasal grooves are quite s
from the primitive mouth-cavity, or mouth inde
which, as we found, likewise makes its appearan
groove-like indentation of the external skin-cove
front of the blind anterior extremity of the intestina

This pair of nasal grooves, as well as the single mouth groove (Fig. 235, *m*), is lined by the horn-plate. The

FIG. 232. FIG. 233. FIG. 234.

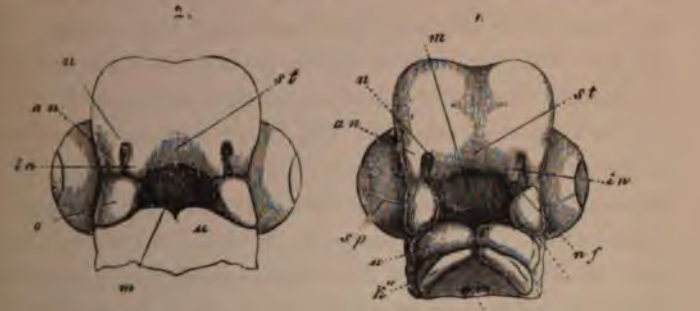


FIG. 235. FIG. 236.

FIGS. 232, 233.—Head of an embryonic Chick, on the third day of incubation: 232, from the front; 233, from the right side. *n*, Nose-rudiment (olfactory grooves); *l*, eye-rudiment (sight-grooves); *g*, ear-rudiment (auditory grooves); *v*, fore-brain; *gl*, eye-slits; *o*, upper jaw process; *u*, lower jaw process of the first gill arch.

FIG. 234.—Head of an embryonic Chick, on the fourth day of incubation, from below: *n*, nose-groove; *o*, upper jaw process of the first gill arch; *u*, lower jaw process of the same; *k''*, second gill-arch; *sp*, choroidal fissure of the eye; *s*, throat (pharynx).

FIGS. 235, 236.—Two heads of embryonic Chicks: 235, at the end of the fourth day; 236, at the end of the fifth day of incubation. The letters as in Fig. 234. Additional letters are *in*, inner, and *an*, outer nasal process; *nf*, nasal furrow; *st*, frontal process; *m*, mouth-cavity. (After Koelliker.)

All these figures are proportionately enlarged.

original separation of the nasal groove from the m
groove is, however, soon interrupted, for the frontal pr
(Fig. 235, *st*, Rathke's "Nasenfortsatz der Stirnwa
is immediately formed above the mouth groove. Right
left the edges of this process project in the form of
lateral processes: these are the inner nasal processe
nasal flaps (Fig. 235, *in*). On each side, opposite to
rises a parallel ridge between the eye and the nasal gr
These ridges are the outer nasal processes (Rathke's "N
dächer," Fig. 235, *an*). Between the inner and
nasal process a channel-like depression thus extend
each side from the nose groove toward the mouth g
(*m*), and this channel is, of course, the same nasal fi
or channel which we found in the Shark (Fig. 231, *r*)
the two parallel edges of the inner and the outer
processes bend towards each other and coalesce abov
nasal channel, the latter becomes a small tube—the prin
"nasal canal." In this stage of its Ontogeny, therefor
nose of Man and of all other Amnion Animals consi
two small narrow tubes—the "nasal canals"—leading
the outer surface of the frontal skin into the simpl
mitive mouth-cavity. This transient condition rese
the permanent condition of the nose in Dipneust
Amphibia. (Cf. Plate I., Frontispiece, with explanati

Specially significant in the modification of the open
channel into the closed nasal canal, is a plug-shaped
tion, which extends from below up to the lower extre
of both the nasal processes on each side, and unites
them. This is the upper jaw process (Figs. 232, *o*,
Plate I., *o*). Below the mouth groove lie the gill
which are separated from one another by the gill op

I., VI., and VII., *k*). The first of these gill arches, at the most interesting to us, which we may call the h, develops the jaw-skeleton of the mouth (Plate I., *u*). l process first grows out from the base of the front n: this is the upper jaw process. The first gill-arch evelops a cartilage on its inner side, called after its rer, "Meckel's cartilage," on the outer surface of he lower jaw forms (Figs. 232, *u*, 236, *u*). The upper cess forms the principal part of the entire framework upper jaw, viz., the palate bone and the wing bone. outer side the upper jaw bone, in the narrower sense, rds arises, while the middle portion of the upper jaw n, the twixt jaw (intermaxillary bone) develops he anterior portion of the frontal process. (See ment of the face in Plate I.)

the further characteristic development of the face in ee higher vertebrate classes, the two upper jaw pro- are of the highest importance. From them proceeds ate roof, the important horizontal partition which into the simple primitive mouth-cavity, separating two quite distinct cavities. The upper cavity, hich the two nasal cavities open, now develops into al cavity—a respiratory air passage and an olfactory The lower cavity, on the other hand, forms, by itself, manent secondary mouth-cavity (Fig. 237, *m*)—the e food passage and the organ of taste. Both the upper avity and the lower taste-cavity open at the back into oat (*pharynx*). The palate roof, separating these two , is formed by the coalescence of two lateral portions e horizontal plates of the two upper jaw processes plates; Fig. 237, *p*). When these do not perfectly

adhere in the middle line, the result is a permanent lo tudinal cleft, through which there is an open passage f the mouth-cavity directly into the nasal cavity. The

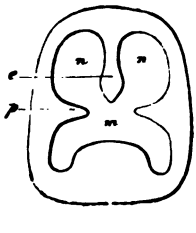


FIG. 237.—Diagrammatic transverse s through the mouth and nose cavity. Whi palate-plates (*p*) separate the original mouth into the lower secondary mouth-cavity (*m*) a upper nasal cavity, the latter is parted by th tical partition wall of the nose (*e*) into two d halves (*n*, *n*). (After Gegenbaur.)

called "wolf's jaws" are thus caused. The "hare-lip" "split lip" is a slighter degree of this arrested de ment.[116]

Simultaneously with the horizontal partition o palate roof, a vertical wall by which the single nasal is divided into two, a right and a left cavity, de (Fig. 237, *n*, *n*). This vertical partition of the nose formed by the middle part of the frontal process: this gives rise by ossification to the vertical lamella o sieve bone (cubiform plate), and below the great ve bony partition wall—the "plough-share" (*vomer*), a front to the twixt-jaw (*os intermaxillare*). Goethe the first to show that in Man, just as in all the other Sk Animals, the twixt-jaw appears as an independent between the two halves of the upper jaw. The ve partition wall of the nose finally coalesces with the horiz palate roof. The two nasal cavities are now as ent separate from one another as from the secondary m cavity. These three cavities open, however, at the into the pharnyx, or jaw-cavity.

double-nostrilled nose has now attained the structure eristic of Man in common with all other Mammals. ther development is very easily intelligible: it is to the formation of internal and external processes walls of both nasal cavities. Within the cavities the "nose shells," spongy bony structures, over which ctory mucous membrane spreads. The first brain he olfactory nerve, with its delicate branches, passes

238, 239.—Upper part of the body of a human embryo (16 mm. in ring the sixth week: Fig. 238, from the left side; Fig. 239, from The origin of the nose in two lateral halves, separate, is still plainly visible. The nose and are disproportionately great in comparison with of the face, especially with the lower lip. llman.)

40.—Face of a human embryo of eight weeks. ker.) Cf. Frontispiece, Plate I. Fig. M1—

from the large brain through the roof of both nasal cavi into the cavities, and extends over the olfactory mu membrane. At the same time, by inversion of the n mucous membrane, the minor cavities of the nose, which afterwards filled with air, and which communicate dire with the two nasal cavities, arise (frontal cavities, caviti the sphenoid bone, jaw cavities, etc.). In this special s of development they occur only in Mammals.[171]

The external nose is not developed until long afte these essential internal parts of the olfactory organ been formed. The first trace in the human embryo ap at the end of the second month (Figs. 238–240). human embryo during the first month shows that origi there is no trace of the external nose. It afterwards g out from the anterior nasal portion of the primitive The form of nose which is characteristic of Man doe appear till a period far later. Much stress is u laid on the shape of the external nose as a noble occurring exclusively in Man; but there are Apes have very human noses, as, for instance, the Nose already mentioned. On the other hand, the external the fine shape of which is so extremely important beauty of the facial structure, possesses in certain ir races of Man a shape anything but beautiful. In Apes the external structure of the nose remains undeve Especially remarkable is the important fact already that it is only in the Apes of the Old World, in the rhines, that the nasal partition wall (*septum*) rema small as it is in Man; in Apes of the New World it considerably at the base, so that the nostrils open out (Platyrhini, p. 175).

TABLE XXX.

Systematic Survey of the Chief Phylogenetic Stages of the Human Nose.

First Stage: Nose of the earlier Primitive Fishes.

The nose is formed by a pair of simple skin-grooves (nose-pits) in the ater surface of the head (like those which are now permanently retained y the lower Selachians).

Second Stage: Nose of the more recent Primitive Fishes.

Each of the two blind nasal grooves becomes connected by a furrow asal-furrow) with one end of the mouth (as is yet permanently the case in he higher Selachians).

Third Stage: Nose of the Dipneusta.

The two nasal furrows change, in consequence of the coalescence of their dges, into closed canals (primary nose-canals), which open at their front nds, within the soft edges of the lip, into the primary mouth-cavity; as is et permanently the case in the Dipneusta and the earlier lower Amphibia *Sozobranchia*).

Fourth Stage: Nose of Amphibia.

The inner openings of the nasal canals penetrate further back into the rimary mouth-cavity, so that they are surrounded by hard bony portions of he jaw (as is yet permanently the case in the higher Amphibia).

Fifth Stage: Nose of the Protamnia.

The primitive mouth-cavity, into which both nasal canals open, separates, n consequence of the formation of a horizontal partition (the palate-roof), nto an upper nasal cavity and a lower (secondary) mouth-cavity. The ormation of the spongy bones of the nose commences (as in the earlier Amnion Animals).

Sixth Stage: Nose of the earlier Mammals.

The simple nose-cavity separates, in consequence of the development of vertical partition wall (the "plough," *vomer*), into two distinct nose-cavities, ach of which is occupied by one of the nasal canals (as is yet the case in all Mammals). The spongy nose-bones differentiate.

Seventh Stage: Nose of the more recent Mammals.

Within both nose-cavities the development of the spongy bones proceeds further, and an external nose begins to form.

Eighth Stage: Nose of the Catarhine Apes.

The internal and the external nose attain the full development exclusively characteristic of Catarhine Apes and of Man.

The history of the development of the eye is equally remarkable and instructive. For although the eye, owing to its exquisite optical arrangement and wonderful structure, is one of the most complex and most nicely adapted organs, yet it develops, without a preconceived design, from a very simple rudiment in the outer skin-covering.

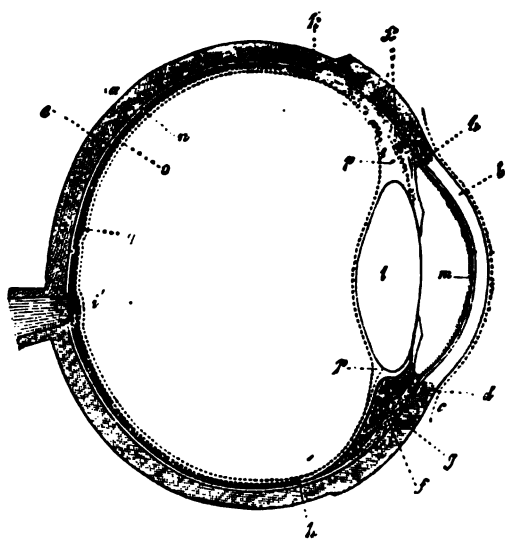


FIG. 241.—The human eye in transverse section: *a*, protective membrane (*sclerotica*); *b*, horn membrane (*cornea*); *c*, outer membrane (*conjunctiva*); *d*, circular veins of iris; *e*, vascular membrane (*choroidea*); *f*, ciliary muscle; *g*, *corona ciliaris*; *h*, rainbow membrane (*iris*); *i*, optic nerve (*n. opticus*); *k*, anterior limit of the retina; *l*, crystalline lens (*lens crystalline*); *m*, inner cover of the horn membrane (water membrane, *membrane Descemeti*); *n*, pigment membrane (*pigmentosa*); *o*, *retina*; *p*, "*petits*-canal;" *q*, yellow spot of the *retina*. (After Helmholtz.)

When fully developed, the human eye is a globula capsule (the eyeball, *bulbus*, Fig. 241). This lies in th

ıy orbit of the skull, surrounded by protective fat and motor muscles. The greater part of this eyeball is ıupied by a semi-fluid, clear gelatinous substance, the reous body (*corpus vitreum*). The crystalline lens ig. 241, *l*) is embedded in the anterior surface of the reous body. It is a lentil-shaped, bi-convex, transparent ly—the most important of the light-refracting media of eye. Among these media is, in addition to the lens l vitreous body, the aqueous humour (*humor aqueus*, at in Fig. 241), in front of the lens. These three pellucid, ht-refracting media—the vitreous body, the crystalline ıs, and the aqueous humour—by which the rays of light, ident on the eye, are refracted and concentrated, are closed in a firm globular capsule consisting of several ferent membranes, comparable with the concentric layers an onion. The outer and thickest of these forms the ıite protective membrane of the eye (*sclerotica*, *a*). It nsists of firm, compact white connective tissue. In front the lens a circular, very convex, transparent plate, rembling a watch glass, is inserted in the white protective embrane; this is the horny membrane (*cornea*, *b*). On outer surface the horny membrane is covered by a very in coating of outer skin (*epidermis*); this coating is lled the connecting membrane (*conjunctiva*); it extends om the horny membrane over the inner surface of both elids—the upper and lower folds of skin which on closing e eyes are drawn together over them. At the inner rner of our eye there is, as a sort of rudimentary organ, e remnant of a third (inner) eyelid, which, as the "nictating membrane," is highly developed in the lower ertebrates (vol. i. p. 110). Below the upper eyelid are lodged

the tear-glands, the secretion of which keeps the su of the eye smooth and clean.

Directly under the protective membrane is a de dark-red, highly vascular membrane, the vascular brane (*choroidea, e*), and within this the retina (*o*), is a dilatation of the optic nerve (*i*). This latter second brain nerve. It extends from the "centre of (the second brain-bladder) to the eye, penetrates the coats of this, and then extends, as the retina, betwe vascular membrane (*choroidea*) and the vitreous (*corpus vitreum*). Between the retina and the va membrane lies another very delicate membrane, is commonly, but wrongly, considered as part of the This is the black pigment membrane (*pigmentosa, l pigmenti, n*), or the "black carpet" (*tapetum ni* It consists of a single layer of beautiful hexagona accurately joined together and filled with black pi granules. This pigment membrane lines, not only th surface of the actual vascular membrane, but also th terior surface of its anterior muscular prolongation, as a circular ring-like membrane, covers the edge of tl and prevents the penetration of lateral rays. This well-known "rainbow membrane" (*iris, h*), which is diff coloured in different persons (blue, gray, brown, etc.). "rainbow membrane" is the limit towards the fi the vascular membrane. The round hole in the iris pupil, through which the rays of light pass into the i of the eye. Where the iris proceeds from the edge actual vascular membrane, the latter is much thicken forms a beautiful ciliated crown (*corona ciliaris, g*), surrounds the edge of the lens with about seventy and many smaller rays.

he embryo of Man, as in that of all other Amphi-
wo pear-shaped vesicles grow out laterally, at a very
eriod, from the foremost part of the first brain-
(Fig. 223, *a*, p. 218). These bladder-like protuberances
primary eye-vesicles. At first they are directed
l and forward, but they soon make their way further
rd, so that after the specialization of the five brain-
, they lie at the base of the twixt-brain. The
spaces within the two pear-shaped vesicles, which
ain a considerable size, communicate through their
stalks with the cavity of the twixt-brain. Their
vering is formed by the outer skin-covering (horn-
d leather-plate). Where, on each side, the latter
irectly in contact with the most curved portion of
nary eye-vesicles, a thickening (*l*) arises, and at the
me a groove-like indentation (*o*) in the horn-plate
2, 1). This groove, which we will call the lens groove,
into a closed sac, the thick-walled lens vesicle (2, *l*),
the fact that the edges of the groove coalesce above

2.—Eye of an embryonic Chick in longitudinal section (1, of a
r sixty-five hours of incubation; 2, of a somewhat older germ;
rm four days old): *h*, horn-plate; *o*, lens groove; *l*, lens (in 1,
ma part of the epidermis, while in 2 and 3 it has separated); *x*,
of the horn-plate at the point from which the lens separated;
body; *r*, retina; *u*, pigment membrane. (After Remak.)

it. Exactly as the medullary tube originally separates fi the outer germ-layer does this lens-sac separate from horn-plate, in which it originated. The space within sac is afterwards entirely filled by the cells of its thick v and the solid crystalline lens is thus formed. The latte therefore, purely a formation of the epidermis. Together the lens the small fragment of the leather-plate (*cori* lying below the lens separates from the outer skin-cove This small piece of the leather-skin very soon forms a hi vascular sac round the lens (*capsula vasculosa le* Its anterior portion at first covers the pupillary orifice is then known as the pupillary membrane (*memb pupillaris*). Its back portion of the same membrane is c the "*membrana capsulo-pupillaris.*" This "vascular capsule, which merely serves to nourish the growing afterwards entirely disappears. The later, permanent capsule contains no vessels, and is a structureless sec of the lens cells.

As the lens thus separates from the horn-plate grows inward, it must necessarily indent the adjc primary eye-vesicles from without (Fig. 242, 1–3). process may be compared to the inversion of the germ- brane vesicle (*blastula*), which in the Amphioxus a many low animals gives rise to the gastrula (vol. i. p. 192 both instances the inversion of one side of the closed v proceeds until finally the inner, inverted portion touch outer, uninverted portion of the wall of the vesicle, s the cavity disappears. Just as in the gastrula the f part changes into the intestinal layer (*entoderma*) the latter into the skin-layer (*exoderma*), so in the in primary eye-vesicle the retina develops from the f

ner) part (Fig. 242, *r*), and the black pigment membrane) from the latter (the outer, uninverted part). The hollow lk of the primary eye-vesicle changes into the optic rve.

The lens (*l*) which enacts so important a part in this verting process of the primary eye-vesicle, lies at first rectly upon its inverted part, that is, on the retina (*r*). ry soon, however, the two separate, a new body, the treous body (*corpus vitreum, gl*), coming in between them. hile the lens-sac is detaching itself, and the primary eye-sicle is being inverted from without, another inversion nultaneously proceeds from beneath—from the superficial rtion of the skin-fibrous layer, *i.e.*, from the leather-plate the head. At the back of the lens and below it, a ledge-like ocess of the leather-plate arises (Fig. 243, *g*), which inverts e primary eye-vesicle (now shaped like a cup) from below, d presses in between the lens (*l*) and the retina (*r*) us the primary eye-vesicle assumes the form of a hood. e opening of this hood, answering to the face, is covered the lens; but the opening, through which the neck ould pass, answers to the indentation through which the ather-skin passes in between the lens and the retina (the ner wall of the hood). The space within this secondary e-vesicle is almost filled by the vitreous body, which swers to the head wrapped in this hood. The hood itself properly speaking, double: the inner hood itself is the tina, and the outer one, directly surrounding the former, the pigment membrane. The comparison with a hood nders this process of inversion, which is sometimes hard explain, more clearly understood. The rudiment of the treous body (*corpus vitreum*) is at first very incon-

siderable (Fig. 243, *g*), and the retina disproportionally thick. As the former expands, the latter becomes much thinner, till at last the retina appears only as a very delicate

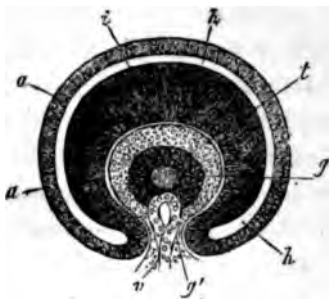


FIG. 243.—Horizontal transverse section through the eye of a human embryo of four weeks; 100 times enlarged (after Koelliker): *t*, lens (the dark wall of which is equal to the diameter of the central cavity); *g*, vitreous body (connected with the leather-plate by a stalk, *g'*); *v*, vascular loop (penetrating through the stalk (*g'*) into the vitreous body behind the lens); *r*, retina (inner, thicker, inverted lamella of the primary eye-vesicle); *a*, pigment membrane (outer, thinner, uninverted lamella of the same); *h*, intermediate space between the retina and the pigment membrane (remnant of the cavity of the primary eye-vesicle).

coat of the thick, almost globular vitreous body, which fills the greater part of the secondary eye-vesicle. The outer layer of the vitreous body changes into a highly vascular capsule, the vessels of which afterwards disappear.

The slit-like passage through which the rudiment of the vitreous body grows from below in between the lens and the retina, of course causes a break in the retina and the pigment-membrane. This break, which appears on the inner surface of the vascular membrane as a colourless streak, has been inaptly called the choroidal cleft, though the true vascular membrane is not cleft at all at this point (Fig. 234, *sp*, 235, *sp*, p. 243). A thin process of the vitreous body passes inward on the under surface of the optic nerve, which it inverts in the same way as the primary eye-vesicle was inverted. The hollow cylindrical optic nerve (the stalk of

imary eye-vesicle) is thus transformed into a channel, ıg downward. The inverted lower surface attaches ;o the uninverted upper surface of the hollow stalk, so he hollow space within the stalk, forming the com- ation between the cavity of the twixt-brain and of imary eye-vesicle, now disappears. The two edges channel now grow downward toward each other, e the band-like process of the leather-plate, and e beneath it. Thus this process now lies within the f the solid secondary optic nerve. It develops into of connective tissue carrying the central blood-vessel retina (*vasa centralia retinæ*).

entirely fibrous covering, the fibrous capsule of the ow finally forms round the outside of the secondary sicle and its stalk (the secondary optic nerve). It ates from the head-plate, from that part of the skin- layer which immediately encloses the eye-vesicle. brous covering takes the form of a completely-closed ar sac, which surrounds the whole ball of the eye, and outer side of this, grows in between the lens and the late. The globular wall of the capsule soon separates, ion of the surface, into two distinct membranes. The membrane becomes the choroidea, or vascular layer; ıt it forms the ciliated crown (*corona ciliaris*) and s. The outer membrane, on the other hand, becomes hite enveloping, or protective membrane (*sclerotica*), n front, forms the transparent horny membrane). The rudiments of all the essential parts of the e now formed, and its further development is only in , in the complex differentiation and combination of eral parts.

TABLE XXXI.

Systematic Survey of the Development of the Human Eye.

I. Systematic Survey of those parts of the Human Eye which develop from the first of th Secondary Germ-layers, the Skin-sensory Layer.

A. Products of the **Marrow-plate**	1. Stem of the primary eye-vesicle	1. Optic nerve	*Nervus opticus*
	2. Inner (inverted) part of the primary eye-vesicle	2. Retina	*Retina*
	3. Outer (uninverted) part of the primary eye-vesicle	3. Screen, or pigment-coat	*Pigmentosa* (lam *pigmenti*)
B. Products of the **Horn-plate**	4. Vesicle separated from the horny plate	4. Crystalline lens	*Lens crystallina*
	5. Outer epidermic skin	5. Connective membrane	*Conjunctiva*
	6. Inverted portions of the epidermic skin	6. Tear-glands	*Glandula lacrym*

II. Systematic Survey of those parts of the Human Eye which develop from the second of Secondary Germ-layers, the Skin-fibrous Layer.

C. Products of the **Leather-plate**	7, 8. Ledge-like process of the corium on the lower side of the primary eye-vesicle	7. Vitreous body 8. Vascular membrane of the vitreous body	*Corpus vitreum* *Capsula vascula corporis vitrei*
	9. Continuation of the corium process	9. Central vessels of the retina	*Vasa centralia retinæ*
	10. Pupillary membrane, with its capsule	10. Vascular membrane of the lens	*Capsula vascula lentis crystalli*
	11. Folds of the leather skin (*corium*)	11. Eyelids	*Palpebræ*
D. Products of the **Skull-plate**	12, 13. Vascular membrane of the eyeball (*capsula vasculosa bulbi*))	12. Vascular membrane 13. Rainbow membrane	*Choroidea* *Iris*
	14, 15. Fibrous membrane of the eyeball (*capsula fibrosa bulbi*)	14. Protective membrane 15. Horny membrane	*Sclerotica* *Cornea*

The most important fact in this remarkable process of -development is the circumstance that the optic nerve, retina, and the pigment-membrane originate from a t of the brain, from a protuberance of the twixt-brain, ile the crystalline lens, the most important refracting dium, develops from the outer skin (*epidermis*). From outer skin—the horny lamina—originates also the icate connecting membrane (*conjunctiva*) which after-rds envelopes the outer surface of the eyeball. The tear-nds proceed, as branched processes, from the conjunctiva g. 214, p. 202). All the other parts of the eye originate m the skin-fibrous layer; the vitreous body and the cular lens-capsule from the leather-plate, the choroid t with the iris, and the protective membrane (*sclerotica*) h the horny membrane (*cornea*) from the head-plates.

The outer protective organs for the eye, the eyelids, are rely simple folds of skin, which, in the human embryo, ear in the third month. In the fourth month the upper lid adheres to the lower, and the eye then remains ered by them till birth. (Plate VII. Fig. *M* III., *R* III.,) The two eyelids usually again separate shortly before th, but sometimes not till after. Our skulled ancestors l, in addition to these, a third eyelid, the nictitating mbrane, which was drawn over the eye from the inner ner. Many Primitive Fishes (*Selachii*) and Amnion imals yet retain this. In Apes and in Man it has atrophied, l only a small remnant of it exists in the inner corner of eye as the "crescent-shaped fold," as a useless "rudi-ntary organ." (Cf. vol. i. p. 109.) Apes and Man have lost the "Harder gland," opening below the nictitating mbrane, which appears in other Mammals, and in Birds, ptiles, and Amphibians.

The ear of Vertebrates develops in many impo points similarly to the eye and nose, but yet in respects very differently.[172] The organ of hearing c developed human being resembles that of other Ma in all essential particulars, and is especially similar to t Apes. As in the latter, it consists of two principal pa apparatus for the conveyance of sound (external and i ear) and an apparatus for producing the sensation of (internal ear). The outer ear opens in the ear-shell (a

FIG. 244.—Auditory organ of man (left ear, seen from the front; size): *a*, ear-shell: *b*, external ear-canal; *c*, drum, or tympanic me *d*, cavity of drum; *e*, ear-trumpet; *f*, *g*, *h*, the three ear bonelets (*f*, h *g*, anvil; *h*, stirrup); *i*, ear-pouch (*utriculus*); *k*, the three semi-canals; *l*, ear-sac (*sacculus*); *m*, snail (*cochlea*); *n*, auditory nerve.

auris), situated at the side of the head (Fig. 224, *a*). this the outer ear-canal, which is usually about an inc leads to the inside of the head (*b*). The inner end c

be is closed by the well-known tympanic membrane drum (*tympanum*); a thin membrane of oval form (*c*), aced in a vertical position, but slightly inclined. This embrane separates the outer ear-canal from the so-called vity of the drum (*cavum tympani*). This is a small vity enclosed in the petrous part of the temporal bone, hich is filled with air and connected by a special tube with e mouth-cavity. This tube is somewhat longer, but much rrower than the outer ear-canal; it leads inward and rward in an oblique direction from the inside wall of the mpanum and opens behind the inner nostrils (or Choana) to the upper part of the cavity of the throat (*pharynx*). his canal is called the Eustachian tube (*tuba Eustachii*). equalizes the pressure of the air in the tympanic vity, and the outer atmospheric air which enters by e ear canal. Both the Eustachian tube and the tympanic vity are lined by a thin, mucous membrane, which a direct continuation of the mucous membrane of the roat. Within the tympanic cavity are the three bonelets the ear, which, from their characteristic shape, are called e hammer, the anvil, and the stirrup (Fig. 244 *f, g, h*). e hammer (*f*) lies furthest outward, just within the mpanic membrane; the anvil (*g*) is wedged in between e two others, above the hammer, and further in than the mmer; and, lastly, the stirrup (*h*) lies next to the anvil ward the inside, and touches with its base the outer wall the internal ear, or the auditory sac. All these parts of e middle and external ear belong to the sound-conducting paratus. Their principal office is to convey the waves of nd from without through the thick side-wall of the head, the internal ear. In Fishes these parts are entirely unre-

presented. In them, the sound-waves are conveyed direct through the wall of the head itself to the internal ear.

The inner apparatus, that which produces the sensatio of sound, receiving the sound-waves thus conveyed to i consists in Man, as in all other Vertebrates (with the sing exception of the Amphioxus), of a closed auditory sac fill with fluid, and of an auditory nerve, the ends of which distributed over the wall of this sac. The vibrations the waves of sound are conveyed by that medium to th nerve-ends. In the auditory fluid (*endolymph*), wh fills the labyrinth, and opposite the places at which auditory nerves enter, are some small stones, compo of a mass of microscopic calcareous crystals (*otoliths*). organs of hearing of most Invertebrates have essenti the same construction. In them, also, it usually consist a closed sac filled with fluid, containing otoliths, and ha the auditory nerve distributed over its wall. But whil Invertebrates the auditory vesicle is usually of a simple spherical or oval form, in all Amphirhina, on contrary, that is, in all Vertebrates above the Fishes u Man, it is distinguished by a very characteristic and sing form known as the auditory labyrinth. This thin mem nous labyrinth is enclosed in a bony envelope of the form, the osseous labyrinth (Fig. 245), which lies withir petrous bone of the skull. The labyrinth in all Amphir is divided into two sacs. The larger sac is called auditory pouch (*utriculus*), and has three curved append called the semi-circular canals (*c, d, e*); the smaller s called the auditory sac (*sacculus*), and is connected wi peculiar appendage, which in Man and the higher Mam is distinguished by a spiral form, like the shell of a snail

ace is called the "snail" (*cochlea, b*). On the thin wall this delicate membranous labyrinth, the auditory nerve, ich passes from the after-brain to the labyrinth, is dis-buted in a very complex manner. It divides into two in branches, the nerve of the cochlea, and the nerve of tibule, for the remaining part of the labyrinth. The mer seems specially to determine the quality of the sound ard, the latter its quantity. The nerve of the cochlea

FIG. 245.—The bony labyrinth of the human ear side): *a*, vestibule; *b*, cochlea; *c*, upper semi-ular canal; *d*, posterior semi-circular canal; *e*, r semi-circular canal; *f*, *fenestra ovalis*; *g*, *fenestra nda*. (From Meyer.)

s us the pitch and quality of sounds, the nerve of the tibule their strength.

The first rudiment of this extremely complex organ of ring is very simple in the human embryo, as in those all other Skulled Animals (*Craniota*); it is a groove-like pression of the outer skin (*epidermis*). At the back of the d, near the after-brain, at the upper end of the second l-opening, a little wart-like thickening of the horn-plate ses on each side (Figs. 246, *A*, *fl*; 248, *g*). This deepens o a small groove, and separates from the outer-skin, just does the lens of the eye. (Cf. p. 253.) A small vesicle ed with fluid, the primitive ear-vesicle, is thus formed each side, immediately below the horn-plate of the back t of the head; this is also called the "primary laby-th" (Plates VI. and VII.). As this separates from its ginal site, the horn-plate, and grows inward and down-rd in the skull, it changes from a globular to a pear-aped form (Figs. 246, *B*, *lv*; 249, *o*). The outer part has

elongated into a thin stalk, which at first opens outward in a narrow canal. (Cf. Fig. 137, *f*, vol. i. p. 382.) This is called the appendage of the labyrinth *recessus labyrinthi*, Fig. 246, *lr*.

FIG. 246.—Development of the ear-labyrinth of a Chick, in five consecutive stages (*A–E*) (cross-sections through the rudimentary skull): *fl*, ear-groove; *lv*, ear-vesicle; *lr*, labyrinth appendage; *c*, rudiment of the cochlea; *csp*, hind semi-circular canal; *cse*, outer semi-circular canal; *jr*, jugular vein. (After Reissner.)

FIGS. 247, 248.—Head of an embryonic Chick, on the third day of incubation: 247 in front, 248 from the right; *n*, rudimentary nose (olfactory groove); *l*, rudimentary eye (ocular groove); *g*, rudimentary ear (auditory groove); *v*, fore-brain; *gl*, eye-slit; *o*, process of the upper jaw; *u*, process of the lower jaw of the first gill-arch. (After Koelliker.)

FIG. 249.—Primitive brain of human embryo of four weeks, in vertical section, and the left half observed from within: *v*, *z*, *m*, *h*, *n*, the five grooves of the skull cavity in which the five brain bladders are situated (fore, twixt, mid, hind, and after brains); *o*, primary, pear-shaped auditory vesicle (showing through); *a*, eye (showing through); *no*, optic nerve; *p*, canal of the hypophysis; *t*, central skull-pieces. (From Koelliker.)

ower Vertebrates, this develops into a peculiar cavity l with calcareous crystals, which in some Primitive es (*Selachii*) remains permanently open, and opens e on the skull (*ductus endolymphaticus*). In Mam-s, on the contrary, the appendage of the labyrinth phies. In these, it is of interest only as a rudimentary n, which has no longer any physiological significance. iseless remnant traverses the osseous wall of the petrous in the form of a narrow canal, and is called the aque- of the vestibule (*aquæductus vestibuli*).

Only the inner and lower part (extended like a bladder) he detached ear-vesicle develops into the differentiated extremely complex structure which is afterwards known he "secondary labyrinth." This vesicle separates at a early stage into an upper, larger section, and a lower, ller section. The former gives rise to the ear-pouch *iculus*) with the three semi-circular canals; from the r proceeds the ear-sac (*sacculus*) with the "snail" *lea*, Fig. 246, *c*). The three semi-circular canals inate as simple pocket-like processes from the ear-ch (Fig. 246, *E*, *cse* and *csp*). In the centre of each of e processes, the two walls coalesce, and separate them-es from the utricle, while their extremities still commu-te with its cavity. In all Double-nostrils (*Amphirhina*) e are three semi-circular canals, as in Man, while of the lostomi the Lampreys have but two, and the Myxinoides one (p. 103). The highly-developed structure of the il" (*cochlea*), which is one of the most delicate and irable products of adaptation in the mammalian body, inally develops very simply as a bottle-like process the ear-sac (*sacculus*). As Hasse has shown, the

various stages in its ontogenetic development still exist permanently side by side in the ranks of the lower Vertebrates.[178] Even in Monotremes the snail-like spiral curving of the cochlea is not present; it is exclusively characteristic of the other Mammals and Man.

The auditory nerve (*nervus acusticus*), or the eighth brain-nerve,—one of the main branches of which distributes itself over the "snail" (*cochlea*), the other over the other parts of the labyrinth,—is, as Gegenbaur has shown, the sensory dorsal branch of a spinal brain-nerve, the motor ventral branch of which is the motor nerve of the facial muscles (*nervus facialis*). Phylogenetically it has, therefore, originated from an ordinary skin-nerve, and is, consequently, of wholly different origin from the optic and olfactory nerves, which represent the two direct processes of the brain. In this respect the organ of hearing differs essentially from the organs of sight and of smell. The auditory nerve originates from the cells of the head-plate; therefore, from the skin-fibrous layer. From this also develop all the membranous, cartilaginous, and bony coverings of the ear-labyrinth.

The development of the apparatus for the conveyance of sound, situated in the middle and external ear of Mammals, is entirely distinct from that of the apparatus of auditory sensation. It must be regarded, phylogenetically as well as ontogenetically, as an independent, secondary formation, which only afterwards connects itself with the primary internal ear. Its development is, however, not less interesting, and is equally clearly explained by Comparative Anatomy. In all Fishes, and in the yet lower Vertebrates, there is no special apparatus for the conveyance of sound,

TABLE XXXII.

Systematic Survey of the Chief Stages in the Development of the Human Ear.

I. *First Stage.*

The auditory nerve is an ordinary sensitive skin-nerve, which, during the differentiation of the horn-plate, appears at a certain point on the skin of the head.

II. *Second Stage.*

The differentiated place of the horn-plate, at which the auditory nerve appeared, forms a small special auditory groove in the skin, which has an outer orifice in the appendage called the "labyrinth."

III. *Third Stage.*

The auditory groove has detached itself from the horn-lamina, and forms a small closed auditory vesicle filled with fluid. The "labyrinth-appendage" becomes rudimentary (*Aquæductus vestibuli*).

IV. *Fourth Stage.*

The auditory vesicle differentiates into two connected parts, the ear-pouch (*utriculus*) and the ear-sac (*sacculus*). Each of the two vesicles receives a special main branch of the auditory nerve.

V. *Fifth Stage.*

Three semi-circular canals grow from the ear-pouch (as in all *Amphirhina*).

VI. *Sixth Stage.*

The "snail" (*cochlea*) grows from the ear-sac in Fishes and Amphibia; it is very insignificant, and is only developed as an independent part in the Amniota.

VII. *Seventh Stage.*

The first gill-opening (the blow-hole of Selachians) changes into the tympanic cavity and the Eustachian tube; the former is externally closed by the tympanic membrane (Amphibia).

VIII. *Eighth Stage.*

The small bones of the ear (*ossicula auditus*) (the hammer (*malleus*) and anvil (*incus*) from the first gill-arch, the stirrup (*stapes*) from the second) develop from parts of the first and second gill-arches.

IX. *Ninth Stage.*

The external ear is developed, together with the bony ear-canal. The shell of the ear is pointed and movable (as in most lower Mammals).

X. *Tenth Stage.*

The ear-shell, with its muscles, becomes disused and a rudimentary organ. It is no longer pointed, but, on the contrary, has a curved rim with a small ear-flap (as in Anthropoid Apes and Men).

TABLE XXXIII.

Systematic Survey of the Development of the Human Ear.

I. Survey of the parts of the Internal Ear. (Apparatus perceptive of sound.)

A. Products of the **Horn-plate**	1. Stalk of the primary ear-vesicle	1. Aqueduct of the vestibule (*Ductus endolymphaticus*)	*Aquæductus vestibuli s. Recessus labyrinthi*
	2, 3. Upper part of the primary ear-vesicle	2. Ear-pouch	*Utriculus*
		3. Three semi-circular, or curved canals	*Canales semi-circulares*
	4, 5. Lower part of the primary ear-vesicle	4. Ear-sac	*Sacculus*
		5. "The snail"	*Cochlea*
B. Products of the **Head-plate**	6. Auditory nerve	6. Auditory nerve	*Nervus acusticus*
	7. Bony covering of the membranous labyrinth	7. Osseous labyrinth	*Labyrinthus osseus*
	8. Bony covering of the whole internal ear	8. "The stony bone"	*Os petrosum*

II. Survey of the parts of the Intermediate and External Ear. (Apparatus for the conveyance of sound.)

C. Products of the first **Gill-opening**	9. Inner part of the first gill-opening	9. Eustachian tube	*Tuba Eustachii*
	10. Central part of the first gill-opening	10. Tympanic cavity (Interior of the drum)	*Cavum tympani*
	11. Closed part of the first gill-opening	11. Tympanic membrane (Head of the drum)	*Membrana tympani*
D. Products of the first two **Gill-arches**	12. Upper part of the second gill-arch	12. Stirrup (First bonelet of the ear)	*Stapes*
	13. Upper part of the first gill-arch	13. Anvil (Second bonelet of the ear)	*Incus*
	14. Central part of the first gill-arch	14. Hammer (Third bonelet of the ear)	*Malleus*
E. Product of the **Head-plate**	15. Tympanic circle (*Annulus tympanicus*)	15. Bony outer auditory passage	*Meatus auditorius osseus*
F. Product of the **Skin-covering**	16. Circular membranous fold at the closed part of the first gill-opening	16. Ear-shell	*Concha auris*
		17. Rudimentary ear-muscles	*Musculi conchæ*

no external and middle ear; in these animals there is only a labyrinth, an internal ear, situated within the skull. The tympanic membrane, its cavity, and all the connected parts are unrepresented. The middle ear first develops in the Amphibian class, in which a tympanic membrane, a tympanic cavity, and an Eustachian tube are first found. All these essential parts of the middle ear develop from the first gill-opening, with its surrounding parts, which in the Primitive Fishes (*Selachii*) remains through life as an open blow-hole, situated between the first and second gill-arches. In the embryos of higher Vertebrates it closes in the centre, the point of concrescence forming the tympanic membrane. The remaining outer part of the first gill-opening is the rudiment of the outer ear-canal. From the inner part originates the tympanic cavity, and further inward, the Eustachian tube. In connection with these, the three bonelets of the ear develop from the first two gill-arches; the hammer and anvil from the first, and the stirrup from the upper end of the second gill-arch.[174]

Finally, as regards the external ear, the ear-shell (*concha auris*), and the outer ear-canal, leading from the shell to the tympanic membrane—these parts develop in the simplest way from the skin-covering which borders the outer orifice of the first gill-opening. At this point the ear-shell rises in the form of a circular fold of skin, in which cartilage and muscles afterwards form (Fig. 238, p. 247). This organ is also limited to Mammals. Among them, it is originally wanting only in the lowest division, in the Beaked Animals, (*Monotrema*). In the others, on the contrary, it appears in very different stages of development and partly also of atrophy. The ear-shell has atrophied in most aquatic

Mammals. Most of these have even lost it entirely; this is so, for example, in the Sea-cows and Whales, and most Seals. On the other hand, in the great majority of Pouched Animals (*Marsupialia*) and Placental Animals (*Placentalia*), the ear-shell is well developed, receives and concentrates the waves of sound, and is provided with a highly-developed muscular apparatus, by means of which it can be turned freely to all sides, and at the same time can be changed in form. Every one must have noticed how strongly and freely our domestic Mammals, Horses, Cows, Dogs, Rabbits, etc., can "prick" their ears, erect them and turn them in different directions. Most Apes yet retain the power of doing this, and our ancient Ape progenitors could also do it. The more

FIG. 250.—Rudimentary ear-muscles on the human skull: *a*, upward muscle (*m. attollens*); *b*, forward muscle (*m. attrahens*); *c*, backward muscle (*m. retrahens*); *d*, larger muscle of the helix (*m. helicis major*); *e*, smaller muscle of the helix (*m. helicis minor*); *f*, muscle of the tragus (*m. tragicus*); *g*, muscle of the antitragus (*m. antitragicus*). (After H. Meyer.)

recent Ape ancestors, common to Men and to the Anthropoid Apes (Gorilla, Chimpanzee, etc.), discontinued the habit of moving their ears, and hence the motor muscles gradually

became rudimentary and useless. We still, however, possess them (Fig. 250). A few individual men can even move their ears forward or backward a little by the use of the forward muscle (*b*) and the backward muscle (*c*); and by long practice these motions can be gradually increased. On the other hand, no man is able to erect the ear-shell by the upward muscle (*a*), or to change its form by the little inner muscles of the ear (*d, e, f, g*). These muscles, which were very useful to our ancestors, have become entirely unimportant to us. This is equally true of Anthropoid Apes.

We also share only with the higher Anthropoid Apes—the Gorilla, Chimpanzee, and Orang—the characteristic form of our human ear-shell, especially the rolled edge, the helix, and the ear-flap. The lower Apes, like all other Mammals, have pointed ears without the helix, and without ear-flaps. Darwin has, however, shown that in some men a short, pointed process, not occurring in most individuals, is perceptible at the upper part of the folded rim of the ear. In some few individuals, this process is very well developed. It can only be explained as the remnant of the original point of the ear which, in consequence of the folding of the edge of the ear, has been bent forward and inward. (Cf. the similarly folded ear in the embryo of the Pig and Cow, Plate VII. Fig. *H* III. and *C* III.) On carefully comparing the ear-shells of Man and of the various Apes in this particular, we find that they form a connected series of retrograde steps. In the common catarhine ancestors of the Anthropoids and of Man, this retrogression began with the folding down of the ear-shell. In consequence of this, the ear-edge was formed on which that significant corner appears, the last trace of the free prominent point of the ear

in our older Ape ancestors. Thus it is possible even here, with the help of Comparative Anatomy, to trace this human organ from the similar but more highly-developed organ of the lower Mammals, with certainty. At the same time, Comparative Physiology shows us that this organ is of more or less high physiological value to the latter, while in Anthropoids and Man it is a useless rudimentary organ. Men with their ears cut off can hear as well as they did before. The conveyance of sound is not affected by the loss of the ear-shell. This explains the great diversity in the form and size of the ear-shell in different persons; it shares this high degree of variability with other rudimentary organs.[175]

CHAPTER XXII.

DEVELOPMENT OF THE ORGANS OF MOTION.

The Motive Apparatus of Vertebrates.—These are constituted by the Passive and Active Organs of Motion (Skeleton and Muscles).—The Significance of the Internal Skeleton of Vertebrates.—Structure of the Vertebral Column.—Formation and Number of the Vertebræ.—The Ribs and Breast-bone.—Germ-history of the Vertebral Column.—The Notochord.—The Primitive Vertebral Plates.—The Formation of the Metamera.—Cartilaginous and Bony Vertebræ.—Intervertebral Discs.—Head-skeleton (Skull and Gill-arches).—Vertebral Theory of the Skull (Goethe and Oken, Huxley and Gegenbaur).—Primitive Skull, or Primordial Cranium.—Its Formation from Nine or Ten Coalescent Metamera.—The Gill-arches (Ribs of the Head).—Bones of the Two Pairs of Limbs.—Development of the Five-toed Foot, adapted for Walking, from the Many-toed Fin of the Fish.—The Primitive Fin of the Selachians (*Archipterygium* of Gegenbaur).—Transition of the Pinnate into the Semi-pinnate Fin.—Atrophy of the Rays or Toes of the Fins.—Many-fingered and Five-fingered Vertebrates.—Comparison of the Anterior Limbs (Pectoral Fins) and the Posterior Limbs (Ventral Fins).—Shoulder Girdle and Pelvis Girdle.—Germ-history of the Limbs.—Development of the Muscles.

"In forming his estimate of my entire theory, the reader may begin with the details and examine the fundamental facts on which I base my conclusions. But it is equally necessary to connect the detached facts, and estimate their bearing on the whole. He who in the world of organisms sees only disconnected existences, in which some organic similarities appear as

accidental coincidences, will remain a stranger to the results of th investigation; not merely because he does not comprehend the conch sions, but principally because the significance of the facts on which the are grounded, escapes him. A fact in itself is no more a scientific resul than a mere collection of facts is a science. That which makes a scien of these facts, is their combination by that organizing mental faculty whi determines the relations of the facts to each other."—KARL GEGENBAU (1872).

AMONG those features of the organization which are speciall characteristic of the vertebrate tribe as such, the peculia arrangement of the motive apparatus, or "locomotorium," undoubtedly occupies a principal place. As in all the higher animals, the active organs of motion, the muscles, form the most important part of this apparatus; these are the fleshy bands which, by means of their peculiar contractibility, of their power of contracting and shortening, move the various parts of the body, and thus change the position of the entire body. The arrangement of these muscles is, however, entirely peculiar in Vertebrates, and differs from the arrangement common to all Invertebrates.

IN most lower animals, especially in Worms, we find that the muscles form a simple, thin flesh-layer immediately below the outer skin-covering. This "skin-muscle pouch" is most intimately connected with the skin itself, and the same feature occurs in the tribe of the Soft-bodied Animals (*Mollusca*). In the great group of the Articulated Animals (*Arthropoda*), in the Crab, Spider, Centipede, and Insect classes, we also find a similar feature, but with the difference that in these the skin-covering forms a hard coat of mail an inflexible skin-skeleton, formed of chitine, and often of carbonated chalk. This outer chitinous coat of mail is jointed in a great variety of ways both on the trunk and

n the limbs of Articulated Animals, and the muscular ystem, the contractile fleshy bands of which are attached o the inside of the chitinous tubes, is correspondingly ointed in an extremely varied manner. The case is exactly eversed in Vertebrates. In these alone an internal hard keleton develops; an inner cartilaginous or bony frame o which the fleshy muscles are externally attached, and in which they find a firm support. This bony frame forms a ombined lever-apparatus, a passive apparatus of motion. The hard parts of this, the arms of the lever, or the ones, are moored against each other by the active movable nuscular bands, as by hawsers. This admirable locomotive pparatus, and especially its firm central axis, the vertebral olumn, is quite peculiar to Vertebrates, on account of which he whole group has long been called that of Vertebrates.

This internal skeleton, notwithstanding the similarity of ts first rudiment, has, however, developed so variously and haracteristically in the different vertebrate classes, and in he higher classes forms so complex an apparatus, that Comparative Anatomy finds one of its richest mines in this eature. This was recognized as long ago as the beginning f the century by the older Natural Science, which at once eized these very welcome materials with peculiar pleasure. That science also, which is now called in the higher and more philosophical sense, "Comparative Anatomy," has eaped its richest harvest from this field. The Comparative Anatomy of the present day has studied the skeleton of Vertebrates more thoroughly, and revealed the laws of its formation more successfully, than has been the case with ny other system of organs of the animal body. Here the well-known and oft-quoted passage, in which Goethe

summed up the general result of his investigations in M phology is especially appropriate:

> "All forms have a resemblance; none is the same as another,
> And their chorus complete points to a mystical law." *

Now that, by the Theory of Descent, we have discove this "mystical law," have solved this "sacred enigma," n that we can explain the similarity of forms by Hered and their dissimilarity by Adaptation, we can find weapon in the whole rich arsenal of Comparative Anato which defends the truth of the Theory of Descent n powerfully than the comparison of the internal skelet of the various Vertebrates. We may, therefore, exp *à priori* that such comparison is of special importance our History of the Evolution of Man. The inner verteb skeleton is one of those organs as to the Phylogeny which Comparative Anatomy affords us conclusions more important and deeper than those to be gained fi its Ontogeny.[176]

More than any other system of organs, the inter skeleton of Vertebrates, when studied comparatively, clea and immediately impresses the observer with the *neces* of the phylogenetic connection between these allied and very varied forms. A thoughtful comparison of the bo frame of Man with that of other Mammals, and of th again with that of lower Vertebrates, is alone sufficient afford conviction of the true tribal relationship of Vertebrates. All the separate parts of which this bo frame is composed appear in other Mammals, in a gr

* "Alle Gestalten sind ähnlich, doch keine gleichet der andern;
Und so deutet der Chor auf ein geheimes Gesetz."

variety of forms indeed, but yet in the same characteristic arrangement and relative position; and if the comparison of the anatomical conditions of the skeleton is carried out below Mammals, we can prove that a direct and uninterrupted connection exists throughout between these various forms which are apparently so utterly unlike, and can finally be traced from a most simple, common, fundamental form. These facts alone must fully convince every adherent of the Theory of Development that all Vertebrates, including Man, must be traced from a single common parent-form, from a Primitive Vertebrate; for the morphological features of the inner skeleton, and of the muscular system which stands in the closest correlative relations to it, are of such a kind that it is quite impossible to conceive a polyphyletic origin, a descent from several different root-forms. It is impossible, on mature reflection, to accept the theory that the vertebral column with its various appendages, or the skeleton of the limbs with their variously differentiated parts, could have originated on several occasions during the course of the earth's history, and that, consequently, the various Vertebrates must be referred in various lines of descent from Invertebrates. Indeed, it is exactly in this point that Comparative Anatomy and Ontogeny irresistibly drive us to the monophyletic conclusion, that the human race is a very recent offshoot of the same great single trunk, from branches of which all other Vertebrates have also sprung.

In order to obtain a view of the outlines of the development of the human skeleton, we must first take a general survey of its arrangement in the developed Man. (Cf. Table XXXIV. and Fig. 251, the human skeleton from the

TABLE XXXIV.

Systematic Survey of the Arrangement of the Human Skeleton.

A. Central Skeleton, or Axial Skeleton. Spine.

A.a. *Vertebral Bodies and Upper Arches.*

1. Skull (*Cranium*)
   - 1 *a.* Pre-vertebral skull
   - 2 *b.* Vertebral skull
2. Vertebral column (*Columna vertebralis*)
   - 7 Neck vertebræ
   - 12 Chest „
   - 5 Hip „
   - 5 Vertebræ of the sacrum
   - 4 „ „ „ tail (*coccyx*)

A.b. *Lower Vertebral Arches.*

1. Products of the gill-arches — *Products of the branchialia*
2. Ribs and breast-bone — *Costæ et sternum*

B. Bones connecting the Extremities.

B.a. *Bones connecting the Anterior Limbs: Bones of the Shoulder.*

1. Shoulder-blade	*Scapula*
(2. Primitive key-bone	*Procoracoides* †)
(3. Raven bone	*Coracoides* †)
4. Collar-bone, or key-bone	*Clavicula*

B.b. *Bones connecting the Lower Limb: Bones of the Pelvis.*

1. Intestinal bone	*Os ilium*
2. Pubic bone	*Os pubis*
3. Hip-bone	*Os ischi*

C. Jointed Skeleton of the Limbs.

C.a. *Skeleton of the Fore Limbs.*

I. First Division: Upper Arm.

1. Upper arm bone	*Humerus*

II. Second Division: Lower Arm.

2. Spoke-bone	*Radius*
3. Ell-bone	*Ulna*

III. Third Division: Hand.

III. A. Wrist	*Carpus*
Original parts.	Modified parts.
a. Radical	= *Scaphoideum*
b. Intermedium	= *Lunatum*
c. Ulnar	= *Triquetrum*
[*d.* Central	= *Intermedium* †]
e. Carpal I.	= *Trapezium*
f. „ II.	= *Trapezoides*
g. „ III.	= *Capitatum*
h. „ IV. + V.	= *Hamatum*

III. *B.* Palm of the Hand	*Metacarpus* (5)
III. *C.* Five Fingers (14 bones	*Digiti Phalanges*)

C.b. *Skeleton of the Hind Limbs.*

I. First Division: Thigh.

1. Thigh-bone	*Femur*

II. Second Division: Leg.

2. Shin-bone	*Tibia*
3. Calf-bone	*Fibula*

III. Third Division: Foot.

III. Ankle	*Tarsus*
Original parts.	Modified parts.
a. Tibial	= *Astragalus*
b. Intermedium	= *Astragalus*
c. Fibular	= *Calcaneus*
d. Central	= *Naviculare*
e. Tarsal I.	= *Cuneiform* I
f. „ II.	= „ II
g. „ III.	= „ III
h. „ IV. + V.	= *Cuboides*

III. *B.* Sole of the Foot	*Metatarsus* (5)
III. *C.* Five Toes (14 bones	*Digiti Phalanges*)

Fig. 251.

Fig. 252.

FIG. 253.—Human vertebral column (in an upright position; from the right side). (After H. Meyer.)

right side (without arms); Fig.
entire skeleton from the front.)
as in all other Mammals, the sk
primarily distinguishable into t
skeleton, or spine, and the skeleto
appendages, or the bony frame of t
The spine consists of the vertebra
and of the skull; the latter being
liarly modified anterior part of th
The ribs are the appendages of the
column; the tongue-bone (*os ling*
lower jaw, and the other product
gill-arches, are those of the sku
skeletons of the two pairs of liml
tremities, are composed of two
parts: of the bony frame of the ac
minent extremities, and of the inn
skeleton, by which the limbs are
to the vertebral column. The gird
ton of the arms (or fore limbs
shoulder girdle; the girdle skelet
legs (or the hind limbs) is th
girdle.

The bony vertebral column in
beings (*columna vertebralis*, or
rium, Fig. 253) is composed of thi
or thirty-four circular pieces of bor
lie one behind the other (one al
other in the usual upright po
man). These bones (*vertebræ*) a
rated from each other by elastic

e intervertebral discs (*ligamenta intervertebralia*), and the same time, are connected by joints, so that the tire vertebral column forms a firm and solid axis, which however, flexible and elastic, capable of moving freely all directions. In the various regions of the trunk, e vertebræ differ in form and connection, so that the llowing are distinguished in the human vertebral column, ginning from above: seven neck-vertebræ, twelve breast-rtebræ, five lumbar-vertebræ, five cross-vertebræ, and ur to five tail-vertebræ. The uppermost, those directly in

Fig. 254.—Third neck-vertebra of man.
Fig. 255.—Sixth breast-vertebra of man.
Fig. 256.—Second lumbar-vertebra of man.

ntact with the skull, are the neck-vertebræ (Fig. 254), d are distinguished by a hole found in each of the o lateral processes. There are seven neck-vertebræ in an, as in nearly all other Mammals, whether the neck long, as in the Camel and the Giraffe, or short, as in the ole and the Hedgehog. The fact that the number of these ck-vertebræ is always seven,—and there are but few ceptions (explicable by adaptation),—is a strong argu-ent for the common descent of all Mammals; it can only accounted for as a strict transmission from a common

parent-form, from some Promammal which had seven
vertebræ. If each animal species had been a distinct
tion, it would have been far more to the purpose to
furnished the long-necked Mammalia with a larger, an
short-necked with a smaller number of neck-vertebræ.
neck-vertebræ are immediately followed by those of the b
or thorax, which, in Man and most other Mammals, nu
twelve or thirteen (usually twelve). Attached to the
of each breast-vertebra (Fig. 255) is a pair of ribs—
curved processes of bone lying in and supporting the w
the thorax. The twelve pairs of ribs, with the conne
intercostal muscles and the breast-bone (*sternum*) const
the breast-body (*thorax*, Fig. 252, p. 279). In this e
and yet firm thorax lie the double lung, and betwee
two halves of this, the heart. The chest-vertebræ
followed by a short but massive section of the vert
column, formed by five large vertebræ. These are
lumbar-vertebræ (Fig. 256), which bear no ribs and
no perforations in their lateral processes. Next come
cross-bone (*sacrum*), which is inserted between the
halves of the pelvic girdle. This cross-bone consists o
fixed and amalgamated cross-vertebræ. Last comes a
rudimentary tail-vertebral column, the rump-bone (*co*
This bone consists of a varying number (usually four,
rarely three or five) of small aborted vertebræ; it
useless rudimentary organ, retaining no physiological
nificance either in Man or in the Tail-less Apes or An
poids. (Cf. Figs. 204–208.) Morphologically it is, how
very interesting, as affording incontrovertible eviden
the descent of Man and of Anthropoids from Long-
Apes. For this assumption affords the only po

explanation of this rudimentary tail. In the human embryo, indeed, during the earlier stages of germ-history, the tail projects considerably. (Cf. Plate VII. Fig. *M* II., and Figs. 123, *s*, 124, *s*, vol. i. p. 370.) It afterwards becomes adherent, and is no longer externally visible. Yet traces of the aborted tail-vertebræ, as well as of the rudimentary muscles, which formerly moved them, persist throughout life. According to the earlier anatomists the tail in the female human being has one vertebra more than that of the male (four in the latter, five in the former).[177]

Number of Vertebræ in various Catarhini.		*Neck Vertebræ.*	*Chest or thoracic Vertebræ.*	*Lumbar Vertebræ.*	*Cross or sacral Vertebræ.*	*Tail Vertebræ.*	*Total.*
Tailless	Man (Fig. 208)	7	12	5	5	4	33
	Orang (Fig. 205)	7	12	5	4	5	33
	Gibbon (Fig. 204)	7	13	5	4	3	32
	Gorilla (Fig. 207)	7	13	4	4	5	33
	Chimpanzee (Fig. 206)	7	14	4	4	5	34
Tailed	Mandril (*Mormon choras*)	7	13	6	3	5	34
	Drill (*Mormon leucophæus*)	7	12	7	3	8	37
	Rhesus (*Inuus rhesus*)	7	12	7	2	18	46
	Sphinx (*Papio sphinx*)	7	13	6	3	24	53
	Simpai (*Semnopithecus melus*)	7	12	7	3	31	60

The number of vertebræ in the human vertebral column is usually thirty-three in all; but it is an interesting fact that this number frequently varies, one or another vertebra failing, or a new, supernumerary vertebra inserting itself. Not unfrequently, also, a rib, capable of free motion, forms on the last neck-vertebra or on the first lumbar-vertebra, so that thus there are thirteen breast, and six neck, or four lumbar vertebræ. In this way contiguous vertebræ in the different sections of the vertebral column may replace each

other. On the other hand, the above comparison
number of vertebræ in different tail-less and tailed Cata
shows considerable fluctuations in these numbers e
this one family.[178]

To understand the history of the development
human vertebral column, we must now study the for
combination of the vertebræ in somewhat greater
The main outline of each vertebra is that of a sign
(Figs. 254–256). The thicker part, which faces the
side, is called the body of the vertebra, and it forms
disc of bone; the thinner forms a semi-circular arc
vertebral arch, which is turned toward the dorsal side
body. The arches of all the consecutive vertebræ are
nected by thin ligaments (*ligamenta intercruralia*) t
space enclosed by them all in common forms a long
In this spinal, vertebral canal lies, as we have seen, t
portion of the central nervous system, the spinal m
The front part of this, the brain, is enclosed in the
cavity, and hence the skull itself is merely the a
section of the vertebral column, modified in a peculi
The base or ventral side of the bladder-shaped brain-
was originally formed by a number of coalescent ve
bodies, the amalgamated upper vertebral arches of
formed the arched or ventral side of the skull.

While the firm, massive vertebral bodies constit
true central axis of the skeleton, the dorsal arches s
enclose and protect the central marrow. Analogous
also develop on the ventral side as a protection
thoracic and abdominal viscera. These inferior or
vertebral arches, proceeding from the ventral side
vertebral bodies, form a canal in many low Vertebr

ich are enclosed the large blood-vessels on the under face of the vertebral column—the aorta and the tail vein. higher Vertebrates most of these inferior vertebral arches lost or become merely rudimentary. But in the breast tion of the vertebral column they develop into strong, dependent bony arches, the ribs (*costæ*). The ribs are, in t, merely large vertebral arches which have become dependent, and have broken their original connection th the vertebral bodies. The gill arches, of which we ve spoken so often, are of similar origin; they are actual ad-ribs in the strictest sense—processes which have tually originated from the lower arches of the skull-rtebræ, and which correspond with the ribs. Even the ode of connection of the right and left halves of the arches the ventral side is the same in both instances. The est is closed in front by the intervention, between the per ribs, of the breast-bone (*sternum*)—a single bone iginating from two corresponding side-halves. The gill-dy is also closed in front by the intervention of a single ce of bone—the *copula lingualis*.

In now turning from this anatomical examination of the nstitution of the vertebral column to the question of its velopment, I may, as regards the first and most important tures in the evolution, refer the reader to the explanation eady given of the germ-history of the vertebral column hap. XII., vol. i. pp. 369–378). In the first place, it is ne-ssary to recollect the important fact that in Man, as in all her Vertebrates, a simple, unarticulated cartilaginous rod first occupies the place of the articulated vertebral column. his firm but flexible and elastic cartilaginous rod is the ll-known notochord (*chorda dorsalis*). In the lowest Ver-

tebrate, the Amphioxus, this persists throughout life very simple form, and permanently constitutes the internal skeleton (Fig. 151, *i*, vol. i. p. 420; Plate XI. F But even in the Mantle Animals (*Tunicata*), the invertebrate allies of Vertebrata, we find this same chord; transitorily in the transient larval tail of (Plate X. Fig. 5, *ch*); permanently in the Append (Fig. 162). The Mantle Animals, as well as the A have undoubtedly inherited the notochord from a c worm-like parent-form, and these primæval worm a are the Chorda Animals (*Chordonia*, p. 91).

Long before any trace of a skull, limbs, etc., appea human embryo or in that of any of the higher Vertel in that early stage when the whole body is represent by the lyre-shaped germ-disc—in t tral line of this latter, directly un primitive groove or medullary fur pears the simple chorda dorsalis. (84–87, vol. i. pp. 297, 298, surfac Figs. 66–70, 89–93, transverse secti Plates IV., V., *ch.*) As a cylindrical traverses the longitudinal axis of t and is equally pointed at both en cells which compose the chord (Fi come, in common with all the othe the skeleton, from the skin-fibro They most resemble certain cartil a special "chordal tissue" is ofte exist; but this must not be reg more than a special form of cartilaginous tissue early period the notochord envelopes itself in a stru sheath (*a*) as clear as glass, which is secreted by its

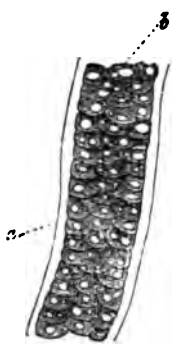
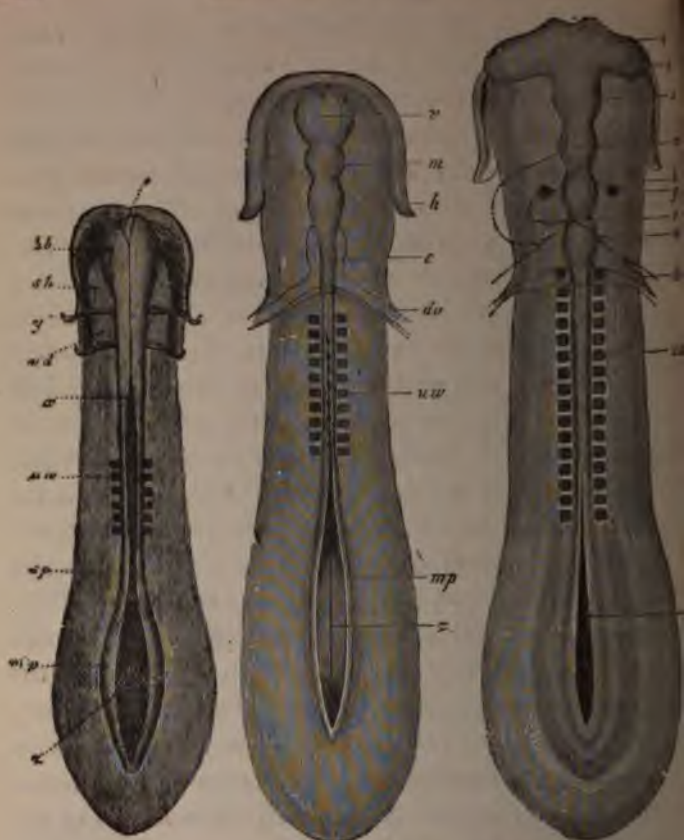


FIG. 257.—Portion of notochord (*chorda dorsalis*) of an embryo sheep: *a*, sheath; *b*, cells. (After Koelliker.)

This perfectly simple, inarticulate, primary axial eton is soon replaced by an articulated, secondary l skeleton, called the "vertebral column." On each side he notochord the primitive vertebral bands or primitive ebral plates (vol. i. p. 306, Fig. 92, *uw*) differentiate from inner portion of the skin-fibrous layer. The inner part hese primitive vertebral bands, which immediately surds the notochord, is the skeleton-plate, or skeleton tum (*i.e.*, the cell-layer forming the skeleton), which ishes the tissue for the rudiments of the permanent ebral column and of the skull. In the anterior half he body the primitive vertebral plate remains a simple, tinuous, unbroken layer of tissue, and soon expands into in-walled vesicle, which surrounds the brain; this is the nordial skull. In the posterior half, on the contrary, primitive vertebral plate breaks up into a number of ologous cube-shaped pieces, lying one behind the other; se are the several primitive vertebræ. The number hese is at first very small, but soon increases, as the n grows in the posterior direction (Figs. 258–260, *uw*). first and earliest primitive vertebræ are the foremost k-vertebræ; the posterior neck-vertebræ then originate; n the anterior breast-vertebræ, etc. The lowest of the -vertebræ arise last. This successive ontogenetic growth he vertebral column in a direction from front to rear y be explained phylogenetically by regarding the manybered vertebrate body as a secondary product, which originated from an originally inarticulate parent-form progressive metameric development, or articulation. t as the many-membered Worms (Earth-worm, Leech) l the closely allied Arthropods (Crabs, Insects) originally



FIGS. 258–260.—Lyre-shaped germ-shield of a Chick, in three consec stages of development; seen from the dorsal side; enlarged about tw times. Fig. 258, with six pairs of primitive vertebræ. The brain is a ple bladder (*hb*). The spinal furrow from *x* remains wide open; behin *z*, it is much enlarged. *mp*, Marrow-plates; *sp*, side-plates; *y*, limit tween the pharynx cavity (*sh*) and the head-intestine (*vd*). Fig. 259, ten pairs of primitive vertebræ. The brain has separated into bladders: *v*, fore-brain; *m*, mid-brain; *h*, hind-brain; *c*, heart; *dv*, veins. The spinal furrow is still wide open (*z*). *mp*, Marrow-pl Fig. 260, with sixteen pairs of primitive vertebræ. The brain has sepa

five bladders: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, hind-brain; *n*, after-brain; *a*, eye-vesicles; *g*, ear-vesicles; *c*, heart; *dv*, yelk-sac; *mp*, marrow-plate; *uw*, primitive vertebra.

veloped from an inarticulate worm-form by terminal dding, so the many-membered vertebrate body has ginated from an inarticulate parent-form. The nearest tant allies of this parent-form are the Appendicularia g. 162) and the Ascidian (Plate XI. Fig. 14).

As has been repeatedly pointed out, this primitive rtebral, or metameric structure has a very important aring on the higher morphological and physiological de-lopment of Vertebrates. (Cf. vol. i. p. 346.) For the articu-ion is by no means confined to the vertebral column, but ually affects the muscular, nervous, vascular, and other stems. As is shown by the Amphioxus, the metameric ucture appeared much earlier in the muscular than in e skeleton system. Each so-called primitive vertebra is fact far more than the mere rudiment of a future verte-a. In each primitive vertebra exists the rudiment of a gment of the dorsal muscles, of a pair of spinal nerve-ots, etc. Only the inner portion—that which lies directly xt to the notochord and the medullary tube—is employed, the skeleton-plate, in the formation of actual vertebræ. e have already seen how these true vertebræ develop from e skeleton-plate of the primitive vertebræ or metamera. he right and left lateral halves of each primitive vertebra, iginally separate, unite. The ventral edges, meeting below e medullary tube, surround the chord and thus form the diments of the vertebral bodies; the dorsal edges, meeting ove the medullary tube, form the first rudiments of the rtebral arches. (Cf. Figs. 95–98, and Plate IV. Figs. 3–8.)

In all Skulled Animals (*Craniota*), most of tl undifferentiated cells which originally constitu skeleton-plate, afterwards change into cartilage cells secrete a firm, elastic "intercellu stance," and thus produce cartil tissue. Like most other parts skeleton, the rudimentary verteb pass into a cartilaginous conditi in the higher Vertebrates, the ginous tissue is afterwards repla the rigid bony tissue with its p radiate bone-cells (Fig. 5, vol. i. The original axis of the vertebral c the notochord, is more or less com by the cartilaginous tissue which vigorously round it. In lower brates (*i.e.*, in Primitive Fishes) or less considerable portion of th chord remains within the ve bodies. In Mammals, on the contrary, it disappears entirely. In the human embryo, even at the end second month, the notochord is seen only as a thin which passes through the axis of the thick cartilagino tebral column (Fig. 261, *ch*). In the cartilaginous ve bodies themselves, which afterwards ossify, the thin re of the notochord (Fig. 262, *ch*) soon disappears entire remnant remains, however, throughout life in the "intervertebral discs" which develop, from the sl plate, between each pair of vertebral bodies (Fig. 2 In a new-born child, a large, pear-shaped cavity, fille a gelatinous cell-mass, is visible in each interverteb

FIG. 261.—Three breast-vertebræ of a human embryo of eight weeks, in lateral longitudinal section: *v*, cartilaginous vertebral bodies; *li*, intervertebral discs; *ch*, notochord. (After Koelliker.)

(Fig. 263, *a*). This "gelatinous nucleus" of the elastic vertebral disc becomes less sharply defined, but persists throughout life in all Mammals, while in Birds and Reptiles, even the last remnant of the notochord vanishes.

FIG. 262.—A breast-vertebra of the same embryo in lateral cross-section: *cv*, cartilaginous vertebral bodies; *ch*, notochord; *pr*, square process; *a*, vertebral arch (upper); *c*, upper end of rib (lower arch). (After Koelliker.)

FIG. 263.—Intervertebral disc of new-born child in cross-section: *a*, remnant of the notochord. (After Koelliker.)

When the cartilaginous vertebræ afterwards ossify, the first deposit of bone-substance (the first "bone-nucleus") in the vertebral bodies is formed immediately round the remnant of the notochord, and soon completely displaces the latter. A special bone kernel or nucleus is then formed in each half of the cartilaginous vertebral arch. It is not till after birth that the ossification progresses so far that the three bone-nuclei approach each other. The two bony halves of the arch unite during the first year, but it is not till much later, till between the eighth and the twelfth year, that they unite with the bony vertebral body.

The bony skull (*cranium*), which must be regarded as

the foremost, peculiarly modified section of the vertebral column, develops in an exactly similar manner. Just as, in the spinal column, the vertebral canal envelopes and protects the dorsal marrow, so the skull forms a bony covering round the brain; and, as the brain is merely the anterior, peculiarly differentiated portion of the dorsal marrow, we might conclude on *à priori* grounds, that the bony envelope of the brain is a peculiar modification of that of the dorsal marrow. It is true, that if the developed human skull (Fig. 264) is considered by itself, it is impossible to understand how it can be merely the modified anterior portion of the vertebral column. It is a complex, capacious bony structure, consisting of no less than twenty bones, differing widely in form and size. Seven of these skull-bones constitute the spacious case which encloses the brain, and in which we distinguish the strong, massive floor of the skull (*basis cranii*) below, and the boldly arched roof of the skull (*fornix cranii*) above. The other thirteen bones form the "facial skull," which especially provides the bony envelopes of the higher sense-organs, and at the same time as the jaw-skeleton, encircles the entrance to the intestinal canal. The lower jaw (usually regarded as the twenty-first skull-bone) is jointed to the skull-floor, and behind this, embedded in the roots of the tongue, we find the tongue-bone, which, like the lower jaw, has originated from the gill-arches, together with a portion of the lower arch, which originally developed as "skull-ribs" from the ventral side of the skull-floor.

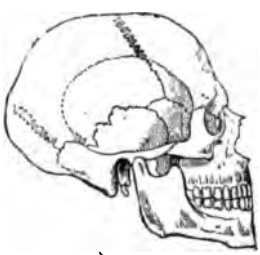


FIG. 264.—Human skull, from the right side.

Although, therefore, the developed skull of the higher 'ertebrates, in its peculiar form, its very considerable size, nd its complex structure, seems to have nothing in ommon with ordinary vertebræ, yet the old comparative natomists at the close of the eighteenth century correctly elieved that the skull is originally merely a series of nodified vertebræ. In 1790, Goethe "picked up out of the and of the Jews' burying-ground among the downs near 'enice, a dismembered skull of a sheep; he at once perceived that the face bones (like the three vertebræ of the ack of the skull) are also derivable from vertebræ." And, n 1806, Oken (without knowing of Goethe's discovery), at lsenstein, on the way to the Brocken, "found a beautifully leached skull of a hind; the thought flashed through him, t is a vertebral column!" [179]

For the last seventy years, this celebrated "Vertebral Theory of the Skull," has interested the most prominent oologists; the most important representatives of Comparative Anatomy have exercised their ingenuity in attempting o solve this philosophical skull-problem; and the question as engaged attention in yet wider circles. It was not till 1872 that the solution was found, after seven years of abour, by the comparative anatomist, who, both in the vealth of his real empirical knowledge and in the profundity of his philosophic speculations, surpasses all other tudents of this science. Karl Gegenbaur, in his classic 'Researches in the Comparative Anatomy of Vertebrates" third part), showed that the skull skeleton of the Selachii s the only record which affords definite proof of the vertebral theory of the skull. Earlier comparative anatomists rred in starting from the developed mammalian skull, and

in comparing the several component bones with the separate parts of vertebræ; they supposed that in this way they could prove that the developed mammalian skull consists of from three to six original vertebræ. The hindmost of these skull-vertebræ was, according to them, the occipital bone. A second and a third vertebra were represented by the sphenoid bone, with the parietal bones, and by the frontal bone, etc. The elements of anterior skull vertebræ were even supposed to exist in the face bones. In opposition to this view, Huxley first called attention to the fact that in the embryo this bony skull originally develops from a simple cartilaginous vesicle, and that in this simple cartilaginous "primitive skull" not the slightest trace of a constitution of vertebrate parts is visible. This is equally true of the skulls of the lowest and most ancient Skulled Animals (*Craniota*), the Cyclostomi and the Selachii. In these the skull retains throughout life the form of a simple cartilaginous capsule—of an inarticulate "primitive or primordial skull." If the older skull-theory, as it was accepted from Goethe and Oken by most comparative anatomists, were correct, then in these lowest Skulled Animals especially, and in the embryos of the higher Skulled Animals, the constitution of the "primitive skull" by a series of "skull-vertebræ" would be very clearly evident.

This simple and obvious consideration, first duly emphasized by Huxley, indeed overturns the famous "Vertebrate Theory of the Skull," as held by the older comparative anatomists. Yet the entirely correct fundamental idea holds good, *i.e.*, the hypothesis that the skull develops from the anterior portion of the spinal column by differentiation and peculiar modification, just as the brain develops from

e anterior portion of the dorsal marrow. But the true ode of empirically establishing this philosophic hypothesis s yet to be discovered; and this discovery we owe to egenbaur.[180] He was the first to employ the phylogenetic ethod, which, in this as in all morphological questions, ads most surely and quickly to the result. He showed at the Primitive Fishes (*Selachii*, Figs. 191, 192, p. 113), s the parent-forms of all Amphirhina, yet retain permanently in their skull-structure that form of primordial kull, from which the modified skull of the higher Vertebrates, and therefore that of Man, has developed phylogenetically. He also pointed out that the gill-arches of the Selachii show that their primordial skull was originally formed of a considerable number—at least nine or ten—primitive vertebræ, and that the brain-nerves, which branch from the base of the brain, entirely confirm this. These brain-nerves—with the exception of the first and the second pairs (the olfactory and the optic nerves)—are merely modified spinal nerves, and, in their peripheric distribution, essentially resemble the latter. The Comparative Anatomy of these brain-nerves is one of the strongest arguments for the newer vertebral theory of the skull.

It would lead us too far aside if we were to enter into the particulars of this ingenious theory of Gegenbaur, and I must content myself with referring to the great work already quoted; in it the theory is fully demonstrated by empirical and philosophical arguments. The same author has given a brief abstract in his "Outlines of Comparative Anatomy" (1874), the study of which it is impossible to recommend too highly. In this work Gegenbaur indicates as original "skull-ribs," or "lower arches of skull-

vertebræ," in the selachian skull (Fig. 265), the follo
pairs of arches: I. and II. are two lip cartilages, of v
the anterior (*a*) consists only of an upper, and the in
(*bc*) of an upper and a lower piece; III., the jaw
which also consists of two pieces on each side,—viz
primitive upper jaw (*os palato-quadratum, o*) and

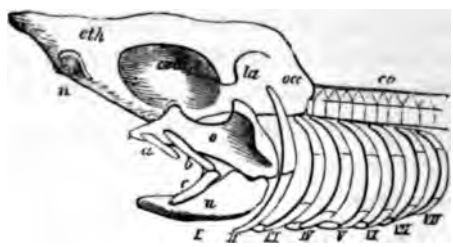


FIG. 265.—Head skeleton of a Primitive Fish: *n*, nose-groove; *eth*, of the sieve-bone; *orb*, eye-cavity; *la*, wall of ear-labyrinth; *occ*, oc region of the primitive skull; *cv*, vertebral column; *a*, front; *bc*, hi cartilage; *o*, primitive upper jaw (*palato quadratum*); *u*, primitive jaw; II., tongue-arch; III.–VIII., first to sixth gill-arches. (After (baur.)

primitive lower jaw (*u*); IV., the tongue arch (II.), and
X., six true gill arches, in the stricter sense of that
(III.–VIII.). The anatomical features of these nine c
skull-ribs, or "lower vertebral arches," and of the
nerves distributed over them, show that the appar
simple, cartilaginous "primordial skull" of the Prin
Fishes originally develops from an equal number (ni
the least) of primitive vertebræ. The base of the sk
formed by the vertebral bodies; the roof of the skull b
upper vertebral arches. The coalescence and amalgam
of these into a single capsule is, however, so ancient,

heir primordial separate condition now appears effaced by he action of the "law of abridged heredity," and is no onger demonstrable in the Ontogeny.

In the human primitive skull (Fig. 266), and in that of ll higher Vertebrates, which has been modified, phylogeetically, from the primitive skull of the Selachii, five conecutive divisions are visible at a certain early period of evelopment; these one might be tempted to refer to five

FIG. 266.—Primitive skull of human mbryo of four weeks; vertical section, e left half seen from the inside: *v*, *z*, , *h*, *n*, the five grooves in the skull vity, in which lie the five brain-bladders ore-brain, twixt-brain, mid-brain, hindrain, after-brain); *o*, pear-shaped priary ear-vesicle; *a*, eye; *no*, optic nerve; canal of the hypophysist; *t*, central rt of the cranial basis. (After Koelliker.)

riginal primitive vertebræ; they are, however, merely the sult of adaptation to the five primitive brain-bladders, nd, like the latter, they rather correspond to a larger umber of metamera. The fact that the primitive vertearate skull is a much modified and profoundly transformed gan, and by no means a primitive structure, is also evient in the circumstance that its rudiment, originally a soft embrane, commonly assumes the cartilaginous state only its base and on the sides, while it remains membranous the skull-roof. Here the bones of the later bony skull velop in the soft membranous rudiment as an external ny roof, without a previous intermediate cartilaginous ate, as in the base of the skull. Thus a great part of the ull-bones originally developed as roof-bones from the

leather-skin (*corium*), and only secondarily, come into c
relations with the skull. How, in Man, this most simple
primordial rudiment of the primitive skull develops, c
genetically, from the head-plates, and how, in the m
time, the anterior extremity of the notochord is enclos
the base of the skull, has already been explained.
vol. i. p. 378; Figs. 145 and 146, p. 393.)

The main features in the history of the developme
the gill-arches, which must now be regarded as skull
has been told. Of the four original rudimentary gill-arc
Mammals (Plates I. and VII., Figs. 232–236, p. 243), the
lies between the primitive mouth-opening and the first
opening. From the base of this gill-arch the "upper
process" develops, and this unites, in the manner al
described, with the internal and the external nasal proc
on each side, and forms the chief parts of the upper jaw s
ton palate-bones, wing-bones, etc. (Cf. p. 245 and 268.)
rest of the first gill-arch, now distinguished as the "lowe
process," forms out of its base two ear bonelets—the ha
(*malleus*) and the anvil (*incus*); the rest of its mass bec
a long strip of cartilage, called, after its discoverer, "Me
cartilage." On the external surface of this cartilage o
ates, as a surface-bone (formed of cellular matter fro
leather-plate), the permanent bony lower jaw. Fro
base of the second gill-arch in Mammalia originat
third ear bonelet, the stirrup (*stapes*), and from the s
quent parts, in order, the stirrup-muscle, the styloid proc
the temporal bone, the styloid band, and the small horn c
tongue-bone. Finally, the third gill-arch becomes cartil
ous only at its anterior portion, and here, by the union
two halves, is formed the body of the tongue-bone (c

dea) and its great horn on each side. The fourth gill- appears in the mammalian embryo only as a transient, mentary embryonic organ, and does not develop into ial parts. Of the posterior gill-arches (the fifth and h pairs), which are permanent in the Primitive Fishes, no e is visible in the embryo of higher Vertebrates. The r have long been lost. The four gill-openings in the an embryo are also only interesting as transient rudi- tary organs, which soon disappear entirely by concre- ce. The first gill-opening (between the first and second arches) alone is of permanent importance; from it lops the drum, or tympanic cavity of the ear, and the tachian tube. (Cf. p. 269, and Plate I., with explan- n.)

Not only did Gegenbaur, in his model "Researches into Comparative Anatomy of Vertebrates," first correctly ain the skull and its relation to the vertebral column, he also first performed the no less weighty and interest- task of showing the phylogenetic derivation of the eton of the limbs in all Vertebrates from one primordial . Few parts of the body in the different Vertebrates subjected, by adaptation to various circumstances, to an infinite variety of modifications as the limbs, in of size, form, and special fitness for certain purposes, and ve are now able to refer them all to one common here- y form. Vertebrates are distinguishable as regards the ture of their limbs into three large main groups. The st and most ancient Vertebrates, the skull-less and jaw- classes, like all their invertebrate ancestors, had no d limbs; this condition is yet represented in the Am- cus and in the Cyclostomi (Figs. 189, 190). The second

main group consists of the two classes of true Fishes, the Dipneusta; in these, two pairs of lateral limbs, shape of many-fingered swimming-fins—one pair of p fins (the fore legs) and one pair of abdominal fins (hind are originally always present (Figs. 191, 192, Plate Finally, the third main group embraces the four vertebrate classes: Amphibia, Reptiles, Birds, and Ma in these the same two pairs of legs exist originally, the form of five-fingered feet. The digits or fing often fewer than five; sometimes, also, the feet ar aborted. But the original parent-form of the entir had anteriorly and posteriorly five digits (Pentadac p. 123).

As regards the Phylogeny of the limbs, fron Comparative Anatomy it appears, therefore, that the mities originated in the Fishes, in the Primitive (*Selachii*), and were transmitted from these to all Vertebrates (all the *Amphirhina*), first in the f many-fingered fins, and afterwards as five-finger (Figs. 267–272). The anterior extremity—the pect (or the fore leg)—is originally shaped precisely l posterior extremity—the ventral fin (or the hind le the one, as in the other, the true limb, externally nent, is distinguishable from the internal, concealed by which the limb is attached to the spinal colum shoulder-girdle above, the pelvic girdle below.

The genuine primitive form of the paired limb existed in the most ancient of the Primitive Fishes the Silurian Period, occurs to this day in perfect pr tion in the ancient Ceratodus, and very curious Mud Australia (p. 119, Plate XII.). In this, both the pecto

ventral fin is a flat, oval paddle, in which we find a ıered or biserial cartilaginous skeleton (Fig. 267). skeleton consists firstly of a strong, articulated fin-rod stem" (Fig. 267, *A B*), which extends from the base to tip of the fin, and secondly, of a double row of thin, ıered rays (*rr*), which are attached to both sides of the ral rod, like the pinnæ of a pinnate leaf. This primi- fin, first recognized by Gegenbaur, and by him called *Archipterygium*, is attached to the spinal column by ns of a simple girdle in the shape of a cartilaginous 181

In some Sharks and Rays, especially when very young, same primitive fin also occurs in a more or less modified ı. But in most Primitive Fishes the fin is already ıtially modified, in that the rays on one side of the stem partly or altogether lost, and are retained only on the r side (Fig. 268). Hence arises the half-feathered, or erial fish-fin, inherited by the other fishes from the chii (Fig. 269).

Gegenbaur first showed how the five-fingered leg of hibia is developed from this uniserial fin (Fig. 270) and ıherited by three classes of Amniota. In those Dip- ta which were the ancestors of the Amphibia, the fin rays ıe other side of the stem also were gradually degraded evelopment, and were in a great measure lost (the light- ıred cartilages in Fig. 269). Only the four lowest rays led in Fig. 269) were retained; and these are the four r digits of the foot (second to fifth digits). The first, reat digit (toe), on the contrary, originated from the r part of the fin-rod. From the middle and upper parts ıis fin-rod developed the long main stem of the limbs

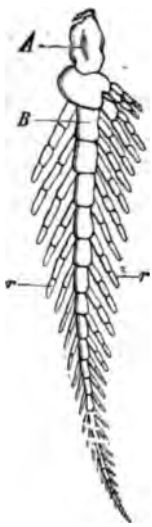


FIG. 267.

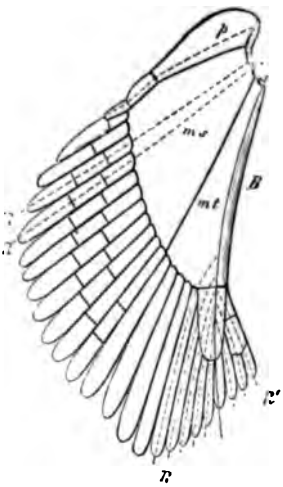


FIG. 268.

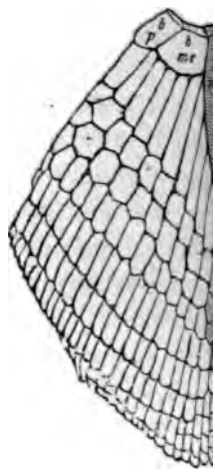


FIG. 269.

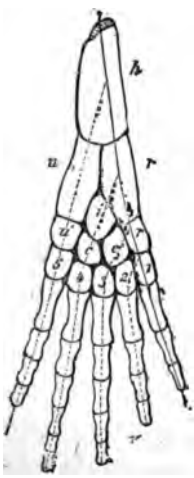


FIG. 270.

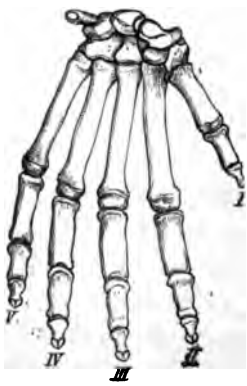


FIG. 271.

FIG. 272

267.—Bones of pectoral fins of Ceratodus (Archipterygium, or pinnate skeleton): *A B*, series of cartilaginous pieces forming the tem of the fin; *rr*, rays of the fin. (After Günther.)

268.—Bones of pectoral fin of an earlier Primitive Fish (Acanthias). he rays of the medial edge of the fin (*B*) have disappeared; only *R'*) remain. *R R*, rays of the lateral edge of fin; *mt*, Metap. ; *ms*, Mezopterygium; *p*, Propterygium. (After Gegenbaur.)

269.—Bones of pectoral fin of a more recent Primitive Fish, or . The rays of the medial edge of the fin have entirely dis- The shaded part on the right is that portion which develops into ngered hand of higher Vertebrates (*b*, the three basal pieces of *mt*, Metapterygium; rudiment of the humerus; *ms*, Mezoptery- Propterygium). (After Gegenbaur.)

270.—Bones of the fore-limb of an Amphibian: *h*, upper arm ; *r*, *u*, lower arm (*r*, *radius*; *u*, *ulna*); *r*, *c*, *i*, *c*, *ů*, root-bones of the row (*r*, radial; *i*, intermediate; *c*, central; *ů*, ulnary); 1, 2, 3, 4, 5, s of the hand, second row. (After Gegenbaur.)

71.—Bones of hand of Gorilla. (After Huxley.)

72.—Bones of human hand, seen from the back. (After H. Meyer.)

s so prominent in the higher Vertebrata as the upper leg) (Fig. 270, *r* and *u*) and the lower arm (or

many-fingered fish-fins thus gave rise, by a process ıal reversion and differentiation, to the five-fingered ıan foot, which occurs first in the Sozobranchia, and rom them, has been transmitted on the one hand to , and to Mammals, up to Man, on the other (Fig. 272). neously with the reduction of the number of the fin- four, a further differentiation affected the fin-stem or became transversely divided into the upper and ms (or legs), and a modification took place in the which in the higher Mammals originally consists, eriorly and posteriorly, of three bones. The simple he original shoulder-girdle separates, on each side upper (dorsal) piece—the shoulder-blade (*scapula*)

and a lower (ventral) piece; the anterior portion (latter constitutes the pro-key (or collar) bone (*proc deum*) and its posterior part the raven-bone (*coracoi* The simple arch of the pelvic girdle breaks up, corre ingly, into an upper (dorsal) piece—the intestinal (*os ilium*), and a lower (ventral) piece; the anterior p of the latter becomes the pubic bone (*os pubis*), ar posterior portion the hip-bone (*os ischii*). Table XX p. 278, shows the correspondence of these three p the pelvic girdle with those of the shoulder-girdle. latter, however, in the key-bone or collar-bone (*clav* possesses a fourth, wanting in the former. (Cf. Gegenb

As in the girdle, so in the trunk of the limbs th originally an absolute agreement between the anteri posterior limbs. The first section of the trunk is sup by a single strong bone—in the anterior limbs, the arm (*humerus*); in the posterior, the upper leg (*f* The second section, on the other hand, contains two b on the anterior extremity the spoke-bone (*radiu* 270, *r*), and the ell-bone (*ulna*, Fig. 270, *u*); in the po the two corresponding bones, the shin-bone (*tibi* calf-bone (*fibula*). (Cf. skeletons in Fig. 196 and 204–208). Moreover, the subsequent small and nu bones of the wrist (*carpus*) and of the ankle (*tarsu* respond; so do the five bones of the middle of th (*metacarpus*) and of the middle of the foot (*metat* Finally, the same is true of the five digits attached t parts, which in their characteristic structure of a se bone-pieces correspond in the anterior and posterior Charles Martins, of Montpellier, an excellent morpl has shown that, in detail, the anterior and posterio correspond.[188]

omparative Anatomy thus shows that the skeleton mbs in Man is composed of the same bones, and in manner as the skeleton in the four higher verte- asses, we may justly infer their common descent ingle parent-form. This parent-form was the most Amphibian possessing five digits both on the fore the hind limbs. The outermost part of the limbs eed, been very much modified by adaptation to conditions of life. The diversities in this point he mammalian class are enormous. The slender the swift Deer and the strong, springy legs of the o, the climbing feet of the Sloth and the digging the Mole, the fins of the Whale and the wings of are all instances. It will, of course, be admitted by hese organs of locomotion are as diverse as possible of size, form, and special function. And yet the bony skeleton is substantially the same in them all. ese different forms of limbs the same characteristic always represented in essentially the same strongly l combination; and here we have a weighty confirm- the theory of descent, such as is hardly afforded by parative Anatomy of any other organ. (Cf. Plate k, vol. ii. of "History of Creation.") True, in the the different Mammals, the skeleton is subject to arrests of development and reversions, in addition due to special adaptation (Fig. 273). Thus, in the (or hand) of the Dog the first digit, or thumb, is Fig. 273 II.). In the Pig (III.) and the Tapir (V.) t has entirely disappeared. So, too, in the Rumi- ., the Ox, Fig. IV.) the second and fifth digits are ted, and only the third and fourth are well deve- l.

loped. Finally, in the Horse, only one digit, the third, i perfectly developed (Fig. VI., 3). And yet all these diver fore-feet, as also the hand of the Ape (Fig. 271) and th human hand (Fig. 272), have originated from the sam common five-fingered parent-form. This is proved, not on by the rudiments of the aborted digits, but also by th homologous disposition of the wrist-bones (Fig. 273, *a–p*) (*Vide supra*, p. 124.)

The same story is also told by the germ-history of th limbs, which is originally identical, not only in all Mammal but in all Vertebrates. However different the limbs of th various Skulled Animals (*Craniota*) afterwards appear i their fully developed state, they nevertheless all origina from the same simple rudiment. (Cf. Plates VI. and VII

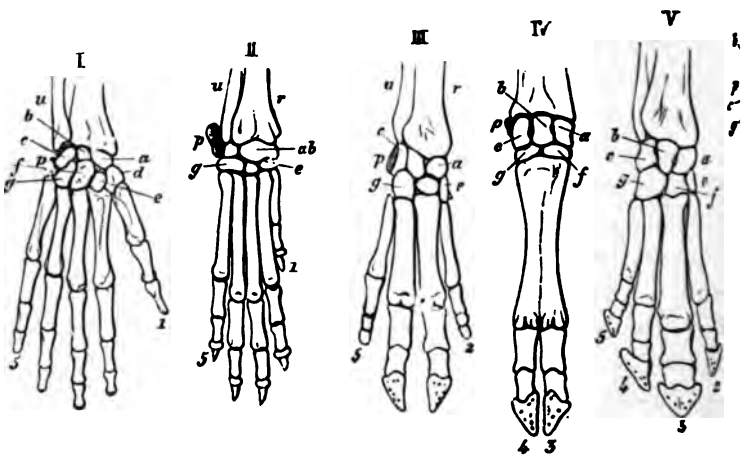


FIG. 273.—Skeleton of hand or fore-foot of six Mammals. I. Man; Dog; III. Pig; IV. Ox; V. Tapir; VI. Horse. *r*, Radius; *u*, ul *a*, scaphoid; *b*, semi-lunar; *c*, triquetrum (cuneiform); *d*, trapezium; trapezoid; *f*, capitatum (unciform process); *g*, hamatum (unciform bo *p*, pisiform; 1, thumb; 2, digit; 3, middle finger; 4, ring finger; 5, li finger. (After Gegenbaur.)

i. p. 362; *f*, fore-leg, *b*, hind-leg.) In all, the first rudi-
ıt of each limb in the embryo is a simple wart, or small
b, which grows from the side of the body between the
sal and ventral sides (Figs. 119 and 120, vol. i. pp. 357, 359;
and 137, pp. 381, 382). The cells composing these knobs
ɔng to the skin-fibrous layer. The outer surface is coated
the horn-plate, which is rather thicker at the apex of
protuberance (Plate IV. Fig. 5, *x*). The two anterior
tuberances appear at a rather earlier period than the
posterior. By differentiation of the cells, these simple
iments develop immediately, in Fishes and in the
ɔneusta, into fins. In the higher vertebrate classes, on
contrary, each of the four protuberances, in the course
ts development, assumes the form of a stalked plate, the
er portion of which being narrower and thicker, the
er broader and thinner. The inner portion, or the handle
the plate, then divides into two sections: the upper and
er legs (or arms). Four notches then appear in the free
ge of the plate, and these gradually become deeper; these
the divisions between the five digits (Plate VIII. Fig. 1).
e latter soon become more prominent. At first, however,
the five digits, both on the fore and on the hind limbs,
joined by a thin connecting web-like membrane; this
alls the original adaptation of the foot as a swimming-fin.
e further development of the limbs from this most simple
liment takes place in the same way in all Vertebrates;
ıt is, by the modification of certain groups of the cells of
skin-fibrous layer into cartilage, of other groups into
ıscles, yet others into blood-vessels, nerves, etc. Probably
differentiation of all these various tissues occurs actually
the limbs. Like the vertebral column and the skull, the

bony parts of the limbs are also formed at first from undifferentiated cell-groups of the skin-fibrous layer. T afterwards change into cartilage, and from these the manent bones originate by a tertiary process.[184]

The development of the muscles, or the active orga locomotion, is, as yet, of much less interest than that o skeleton, or the passive instruments of motion. The parative Anatomy of these is, indeed, of much highe portance than their Embryology. But as very little atte has, as yet, been paid to the Comparative Anatomy Ontogeny of the muscular system, we have only general ideas of its Phylogeny also. The muscular sy as a whole has developed in the most intimate reci correlation with the bone system.[185]

TABLE XXXV.

STEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN SKELETON.

I. *First Period: Skeleton of the Chordonia* (Fig. 187, p. 90).

The entire skeleton is formed by the notochord.

II. *Second Period: Skeleton of the Acrania* (Fig. 189, p. 91).

A notochord-membrane, the dorsal continuation of which forms a cover-g round the medullary tube, is formed round the notochord.

III. *Third Period: Skeleton of the Cyclostomi* (Fig. 190, p. 103).

A cartilaginous primordial skull develops round the anterior extremity the notochord, from the notochord-membrane. An outer cartilaginous ll-skeleton forms round the gills.

IV. *Fourth Period: Skeleton of the older Selachii* (Fig. 268, p. 302).

A primitive vertebral column, with upper and lower arches (the gill-rches and ribs) forms round the notochord. The remnant of the outer gill-keleton remains with the inner. Two pairs of limbs, with pinnate (biserial) keletons, appear.

V. *Fifth Period: Skeleton of the more recent Selachii* (Fig. 269, p. 302).

The anterior gill-arches change into lip-cartilage and jaw-arches. The xternal gill-skeleton is lost. The skeleton of the two pairs of fins becomes niserial (semi-pinnate).

VI. *Sixth Period: Skeleton of the Dipneusta* (Fig. 2, Plate XII.).

The skull becomes partially ossified; as does the shoulder-girdle.

VII. *Seventh Period: Skeleton of the Amphibia* (Fig. 270, p. 302).

The gill-arches are modified into parts of the tongue-bone, and of the jaw-pparatus. On the semi-pinnate skeletons of the fins the rays diminish in umber to four, thus giving rise to the five-toed foot. The vertebral olumn ossifies.

VIII. *Eighth Period: Skeleton of the Monotremata* (Fig. 196, p. 14

The vertebral column, skull, jaws, and limbs, acquire the de characteristics of Mammals.

IX. *Ninth Period: Skeleton of the Marsupialia* (Fig. 197, p. 15

The coracoid bone of the shoulder-girdle becomes atrophied, an remnant of it amalgamates with the shoulder-blade.

X. *Tenth Period: Skeleton of the Semi-apes* (Fig. 199, p. 164

The pouch-bones, which distinguish Monotremes and Mars disappear.

XI. *Eleventh Period: Skeleton of the Anthropoid Apes* (Figs. 204–208, p. 179).

The skeleton acquires the peculiar development shared by M clusively with the Anthropoid Apes.

CHAPTER XXIII.

DEVELOPMENT OF THE INTESTINAL SYSTEM.

The Primitive Intestine of the Gastrula.—Its Homology, or Morphological Identity in all Animals (excepting the Protozoa).—Survey of the Structure of the Developed Intestinal Canal in Man.—The Mouth-cavity.—The Throat (*pharynx*).—The Gullet (*œsophagus*).—The Wind-pipe (*trachea*) and Lungs.—The Larynx.—The Stomach.—The Small Intestine.—The Liver and Gall-bladder.—The Ventral Salivary Gland (*pancreas*).—The Large Intestine.—The Rectum.—The First Rudiment of the Simple Intestinal Tube.—The Gastrula of the Amphioxus and of Mammals.—Separation of the Germ from the Intestinal Germ Vesicle (Gastrocystis).—The Primitive Intestine (Protogaster) and the After Intestine (Metagaster).—Secondary Formation of the Mouth and Anus from the Outer Skin.—Development of the Intestinal Epithelium from the Intestinal-glandular Layer, and of all other parts of the Intestine from the Intestinal-fibrous Layer.—Simple Intestinal Pouch of the Lower Worms.—Differentiation of the Primitive Intestinal Tube into a Respiratory and a Digestive Intestine.—Gill-intestine and Stomach-Intestine of the Amphioxus and Ascidian.—Origin and Significance of the Gill-openings.—Their Disappearance.—The Gill-arches and the Jaw-skeleton.—Formation of the Teeth.—Development of the Lungs from the Swim-bladder of Fish.—Differentiation of the Stomach.—Development of the Liver and Pancreas.—Differentiation of the Small and Large Intestines.—Formation of the Cloaca.

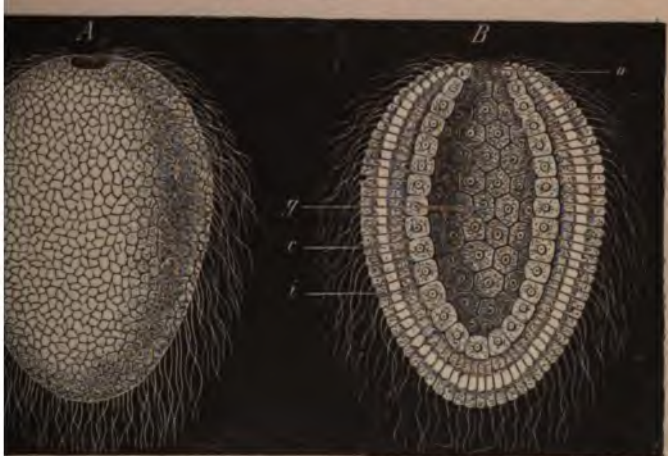
"Cautious people require us to confine ourselves to gathering materials, and to leave it to posterity to raise a scientific structure from those materials; because only in that way can we escape the ignominy of having the theories we believed in overthrown by the advance of knowledge. The unreasonableness of this demand is apparent enough from the fact that

Comparative Anatomy, like every other science, is endless; and th
the endlessness of the accumulation of materials would never allow
they complied with this demand, to reap any harvest from this field.
further than this, history teaches us clearly, that no age in which sc
inquiry has been active, has been able so to deny itself, as, setting t
of its researches in the future, to refrain from drawing conclusions fo
from its larger or smaller treasury of observations, and from trying to
gaps with hypotheses. It would, indeed, be a hopeless proceeding
order to avoid losing any part of our possessions, we should re
acquire any possessions whatever."—KARL ERNST BAER (1819).

AMONG the vegetative organs of the human body, t
development of which we now turn our attention, the
tinal canal is the most important. For the intestine
is the oldest of all the organs of the animal body
carries us back to the earliest time of organological
entiation, to the first period of the Laurentian Epoch
we have already seen, the result of the first divis
labour in the homogeneous cells of the earliest many
animal body must have been the formation of a nu
intestinal canal. The first duty and the first need of
organism is self-support. This task is accomplished
two functions of nutrition and of the covering of the
When, therefore, in the primæval collection of homog
cells (*Synamœbium*), of the phylogenetic existence of
we yet have evidence in the ontogenetic develop
form of the mulberry-germ (*Morula*), the several m
of the community began to divide the work of life
were first obliged to engage in two separate tasks.
half modified into nutritive cells, enclosing a di
cavity, the intestinal canal; the other half, on the co
developed into covering cells, forming the outer
ing of this intestinal canal, and, at the same time,
whole body. Thus arose the first two germ-layer

nutritive, or vegetative layer, and the outer, covering, mal layer.

we try to construct for ourselves an animal body of mplest conceivable form, possessing such a primitive inal canal, and the two primary germ-layers forming all, the result is necessarily the very remarkable form of the gastrula, which we have shown to exist onderful uniformity throughout the whole animal



274.—Gastrula of a Chalk-sponge (Olynthus): *A*, from outside; ngitudinal section through the axis; *g*, primitive intestine; *o*, primi- ith; *i*, intestinal layer, or entoderm; *e*, skin-layer, or exoderm.

in the Sponges, Sea-nettles (*Acalephæ*), Worms, odied Animals (*Mollusca*), Articulated Animals (*Arthro-* and Vertebrates (Figs. 174–179, p. 65). In all these s animal tribes the gastrula reappears in the same ly simple form (Fig. 274). Its whole body is really the intestinal canal; the simple cavity of the body, gestive intestinal cavity, is the primitive intestine

(*protogaster*, *g*); its simple opening, the primitive mouth (*protostoma*, *o*), is at once mouth and anus; and the two cell-strata which compose its wall, are the two primary germ-layers: the inner, the nutritive, or vegetative germ-layer, is the intestinal layer (*entoderma*, *i*); and the outer, covering layer, which, by means of its cilia, is also the agent of motion, is the animal layer, or skin-layer (*exoderma*, *e*). This highly important fact, that the gastrula appears as an early larval condition in the individual development of the most varied animals, and that this gastrula always exhibits the same structure, and that the very differently developed intestinal canals of the most varied animals, arises, ontogenetically, from the same extremely simple gastrula-intestine, this very important fact justifies, in accordance with the fundamental law of Biogeny, two conclusions, which involve important results, and of which one is general and one special. The general conclusion is an inductive one, and may be stated thus: The very variously formed intestinal canal of all the different Intestinal Animals has developed, phylogenetically, from one common and extremely simple primitive intestine, from the intestinal cavity of the Gastræa, that primæval common parent-form which is at the present reproduced, in accordance with the fundamental law of Biogeny, in the gastrula. The second, the special conclusion, which is connected with the former, is deductive, and may be stated thus: The intestinal canal in Man as a whole is homologous with the intestinal canal in all other animals; it has the same original significance, and has developed from the same rudimentary form.[188]

Before proceeding to trace the history of the development of the human intestinal canal in detail, it will be

necessary briefly to get a correct idea of the more general conditions of the formation of the intestinal canal in the developed Man. Not until this is known can the development of the several parts be correctly understood. (Cf. Plates IV. and V., vol. i. p. 321.) The intestinal canal in the developed Man is, in all essential points, exactly similar in form to those of all other higher Mammals, and, especially, to that of the Catarhines, the Narrow-nosed Apes of the Old World. The entrance to the intestinal canal is the mouth-opening (Plate V. Fig. 16, *o*). Food and drink pass first through this into the mouth-cavity, in the lower part of which is the tongue. The human mouth-cavity is hedged with thirty-two teeth, attached in two rows to the two jaws, the upper and lower. It has already been stated that the series of teeth is formed in Man exactly as in the Catarhine Apes, but differs from the corresponding part in all other animals (p. 173). Above the mouth-cavity is the double nose-cavity; the two parts of this are separated by the partition-wall of the palate. But, as we have seen, the nasal cavity is not originally separated at all from the mouth-cavity, a common nasal and mouth cavity being primarily formed in the embryo, and this separates at a later period into two separate stories by the hard palate-roof: the upper is the nasal cavity, the lower is the mouth-cavity. The nasal cavity is connected with certain air-filled bony cavities; the jaw-cavities in the upper jaw, the frontal cavities in the frontal bone, and the sphenoid cavities in the sphenoid bone. Numerous glands of various kinds open into the mouth-cavity, particularly many small mucous glands and three pairs of large salivary glands.

The human mouth-cavity is half closed at the back by

the vertical curtain which we call the soft palate, i
the centre of the lower part of which is situat
uvula. A glance with the mouth open into a m
sufficient to show the form. The uvula is of imp
because it occurs only in Men and in Apes. On bo
of the soft palate are the tonsils (*tonsillæ*). Thro
gate-like arched opening situated beneath the soft
we pass into the throat-cavity (*pharynx;* Plate
16, *sh*), which lies behind the mouth-cavity. This
partly visible in the open mouth when reflected
mirror. Into the throat-cavity a narrow passage o
each side (the Eustachian tube of the ear), whic
directly into the tympanic cavity of the ear (Fig
p. 260). The throat-cavity is continued into
narrow tube, the gullet (*œsophagus, sr*). Throu
the masticated and swallowed food passes down i
stomach. The wind-pipe (*trachea, lr*) also opens i
upper part of the throat, and leads thence to th
The opening of this is protected by the epiglotti
which the food passes. The respiratory organs, t
lungs (Plate IV. Fig. 8, *lu*), are situated, in Man, a
Mammals, in the right and left sides of the breast
(*thorax*), and midway between them is the hear
8, *hr, hl*). At the upper end of the wind-pipe (*t*
below the epiglottis just spoken of, is a peculiarly
entiated section, the larynx, which is protected by a
laginous frame. The larynx is the most important
of the human voice and speech, and also develops
part of the intestinal canal. In front of the larynx
thyroid gland (*thyreoidea*), which occasionally enla
the so-called "goitre."

The gullet (*œsophagus*) passes downward through the thorax, along the vertebral column, behind the lungs and the heart, and enters the ventral cavity, after penetrating the diaphragm. The latter (Fig. 16, *z*) is a membranous, muscular, transverse partition, which in all Mammals (and only in these) completely separates the chest-cavity (*thorax*, $c_{,}$) from the ventral cavity ($c_{,,}$). As has been said, this division does not originally exist; at first a common chest and ventral cavity, the cœloma, or the pleuro-peritoneal cavity, is formed in the embryo. It is only afterwards that the diaphragm forms a muscular, horizontal partition between the chest and the ventral cavities. This partition then completely separates the two cavities, and is penetrated only by separate organs passing through the

FIG. 275.—Human stomach and gall-intestine in longitudinal section: *a*, cardia (limit of the œsophagus); *b*, fundus (blind sac of the left side); *c*, pylorus fold; *d*, pylorus valve; *e*, pylorus-cavity; *f g h*, gall-intestine; *i*, mouth of the gall-duct and of the pancreas duct. (After H. Meyer.)

chest-cavity into the ventral cavity. One of the most important of these organs is the gullet (*œsophagus*). After this has passed through the diaphragm into the ventral cavity it enlarges into the stomach in which digestion

especially takes place. The stomach of an adult [illegible] (Fig. 275, Plate V. Fig. 16, *mg*) is an oblong sac, [illegible] somewhat obliquely, the left side of which widens [illegible] a blind-sac, the base of the stomach or fundus (*b*), which [illegible] right side narrows, and passes at the right end, [illegible] the pylorus (*e*), into the small intestine. Between these [illegible] parts of the intestine is a valve, the pyloric valve (*d*), which [illegible] only opens when the food-pulp (chyme) passes from [illegible] stomach into the small intestine. The stomach itself is [illegible] most important digestive organ, and serves especially [illegible] dissolve the food. The muscular wall of the stomach [illegible] comparatively thick, and, on the outside, has strong muscle [illegible] layers, which effect the digestive movements of the [illegible] stomach;—on the inside, it has a great number of small [illegible] glands, the gastric glands, which secrete the gastric juice.

Next to the stomach follows the longest part of the whole intestinal canal, the central, or small intestine (*chylogaster*). Its principal function is to effect the absorption of the fluid mass of digested food, or the food-pulp (chyme), and it is again divided into several sections, the first of which, the one immediately following the stomach, is called the gall-intestine, or "twelve-finger intestine" (*duodenum*, Fig. 275, *f g h*). The gall-intestine forms a short loop curved like a horse-shoe. The largest glands of the intestinal canal open into it: the liver, the most important digestive gland, which furnishes the bile, or gall, and a very large salivary gland, the ventral salivary gland, or pancreas, which secretes the digestive saliva. Both of these glands pour the juices they secrete, the bile and pancreatic juice, into the duodenum (*i*) near each other. In adults the liver is a very large gland, well supplied with blood, lying on the

side immediately below the diaphragm, and separated the latter from the lungs (Plate V. Fig. 16, *lb*). The reas lies somewhat further back and more to the (Fig. 16, *p*). The small intestine is so long that it to lie in many folds in order to find room in the limited e of the ventral cavity; these coils are the bowels. y are divided into an upper intestine, called the empty stine (*jejunum*), and a lower, the crooked intestine *m*). In this latter part lies that part of the small stine at which, in the embryo, the yelk-sac opens into intestinal tube. This long, thin intestine then passes to the large intestine, from which it is separated by a eculiar valve. Directly behind this "Bauhinian valve" he first part of the large intestines forms a broad pouch-ike expansion, the blind intestine (*cœcum*), the atrophied xtremity of which is a well-known rudimentary organ, the ermiform process (*processus vermiformis*). The large intestine (*colon*) consists of three parts; an ascending part on the right, a transverse central part, and a descending part on the left. The latter finally curves like an S, called the "sigmoid flexure," into the last part of the intestinal canal, above the rectum, which opens at the back by the anus (Plate V. Fig. 16, *a*). Both the large intestine and the small intestine are furnished with numerous glands, most of them very small, and which secrete mucous and other juices.

Along the greater part of its length the intestinal canal is attached to the inner dorsal surface of the ventral cavity, or to the lower surface of the vertebral column. It is fastened by means of the thin, membranous plate, called the mesentery, which develops directly under the notochord

from the intestinal-fibrous layer, at the point when curves into the outer lamina of the side-layer, into skin-fibrous layer (Plate IV. Fig. 5, *g*). The curving was distinguished as the middle-plate (Fig. 99, *mp*). mesentery is, at first, very short (Plate V. Fig. 14, *g*); soon lengthens considerably at the central part of the tinal canal, and takes the form of a thin, transp membranous plate, which has to be the more extend further the folds of the intestine diverge from the where they are first attached to the vertebral column blood-vessels, lymphatic vessels, and nerves which the intestinal canal traverse this mesentery.

Although, therefore, the intestinal canal, in the human being forms an extremely complex orga though it shows in its details so many intricate and d structural arrangements,—into which we cannot here,—this entire structure has developed, histo from that simplest form of primitive intestine was possessed by our gastræad ancestors, and whi extant gastrula now exhibits. We have already sho Chapter VIII.) that the peculiar Hood-gastrula (*A gastrula*) of Mammals (Fig. 277) may be referred to the original Bell-gastrula (*Archigastrula*) form, among Vertebrates, is now accurately retained sol the Amphioxus (Fig. 276; Plate X. Fig. 10).

Like the latter, the gastrula of Man and of all mals must be regarded as the ontogenetic reprod of that phylogenetic evolution-form which we ca Gastræa, and in which the whole body of the ani intestine.

The peculiar form and mode in which the co

an intestinal canal develops from the simple gastrula which is similar to that in other Mammals, can therebe only correctly understood when it is considered in light of Phylogeny. We must, accordingly, distinguish

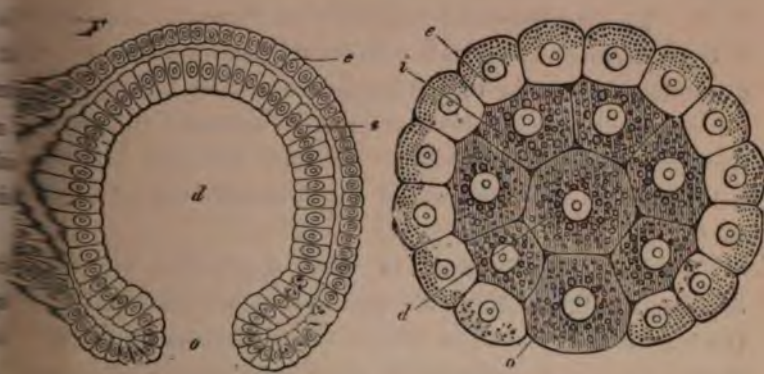


FIG. 276.—Archigastrula of Amphioxus (in longitudinal section): *d*, primitive intestine; *o*, primitive mouth; *i*, intestinal layer; *e*, skin-layer.

FIG. 277.—Amphigastrula of Mammal (in longitudinal section). The primitive intestine (*d*) and primitive mouth (*o*) are filled up by the cells of the intestinal layer (*i*); *e*, skin-layer.

between the original primary intestine ("the primitive intestine, or *protogaster*") of the Skull-less Animals (*Acrania*), and the differentiated or secondary intestine ("after intestine, or *metagaster*") of the Skulled Animals (*Craniota*). The intestine of the Amphioxus (the representative of the *Acrania*) forms no yelk-sac, and develops, palingenetically, from the entire primitive intestine of the gastrula. The intestine of the Skulled Animals, on the other hand, has a modified, kenogenetic form of evolution, and differentiates at a very early period into two different parts: into the permanent secondary intestine, which alone

gives rise to the various parts of the differentiated intestinal system, and the transient yelk-sac, which serves only as a storehouse of materials for the building of the embryo. The yelk-sac attains its greatest development in Primitive Fishes (*Selachii*), Bony Fishes (*Teleostei*), Reptiles, and Birds. In Mammals, and especially in Placental Animals, it is atrophied. The peculiar intestinal development of the Cyclostomi, Ganoids, and Amphibia must be regarded as an intermediate form, between the palingenetic intestinal development of the Skull-less animals, and the kenogenetic intestinal development of the Amnion Animals (*Amniota*).[187]

We have already seen in what a peculiar way the development of the intestine takes place ontogenetically in the human embryo and in that of other Mammals. Immediately from the gastrula of these originates a globular intestinal germ-vesicle (*gastrocystis*), filled with fluid (Figs. 72, 73, vol. i. p. 289). In the wall of this is formed the lyre-shaped germ-shield, on the lower side of which, along the middle line, appears a shallow groove, the first rudiment of the future, secondary intestinal tube.

This intestinal groove grows constantly deeper, and its edges curve toward each other, to grow together at last and form a tube (Fig. 100, vol. i. p. 333). The wall of this secondary intestinal tube consists of two membranes of the inner, intestinal-glandular layer, and of the outer, intestinal-fibrous layer. The tube is completely closed at the ends, having only an opening in the centre of the lower wall, by which it is connected with the intestinal germ-vesicle (Plate V. Fig. 14). The latter, in the course of development, becomes continually smaller, as the intestinal canal continues

to grow larger and more perfect. While, at first, the intestinal tube appears only as a little appendage on one side of the great intestinal germ-vesicle (Fig. 278), the remnant of the latter afterwards forms only a very inconsiderable appendage of the great intestinal canal. This appendage is the yelk-sac, or navel-vesicle. It entirely loses its importance, and at length disappears, while the intestinal canal is finally closed at the original central opening, where it forms the so-called intestinal navel (Fig. 94, vol. i. p. 312).

It has also been said that this simple cylindrical intestinal tube, in Man as in all Vertebrates, is at first entirely closed at both ends (Plate V. Fig. 14), and that the two permanent openings of the intestinal canal—at the anterior extremity, the mouth, at the posterior, the anus—form only secondarily, and from the outer skin. At the fore end, a shallow mouth-furrow originates in the outer skin, and this grows toward the blind, anterior end of the head intestinal cavity, into which it finally breaks. In the same way a shallow furrow for the anus is formed behind in the skin, and this soon grows deeper, and grows toward the blind posterior end of the pelvic intestinal cavity, with which it finally unites. At both extremities there is, at first, a thin partition between the outer skin-furrow and the blind end of the intestine, and this disappears when the opening is made.[188]

Directly in front of the anus the allantois grows out of the posterior intestine; this is the important embryonic appendage which develops, in Placental Animals, and only in these (thus in Man too) into the placenta (Figs. 278, 279, *l*; Plate V. Fig. 14, *al*). In this more developed form—represented in the diagram (Fig. $94_{,4}$, vol. i. p. 312)—the intestinal

canal of Man, like that of all other Mammals, now form slightly-curved, cylindrical tube, which has an opening both ends, and from the lower wall of which depend t sacs; the anterior navel-bladder, or yelk-sac, and the p terior allantois, or primitive urinary sac.

Microscopic observation shows that the thin wall of simple intestinal tube and of its two bladder-like appe ages is composed of two distinct cell-strata. The in which coats the entire cavity, consists of larger, darker c

FIG. 278.—Human embryo of the third week, with the amnio allantois. The great globular yelk-sac is below, the bladder-like alla on the right; there are as yet no limbs. The germ, with its appendag enclosed in the tufted membrane (*chorion*).

FIG. 279.—Human embryo, with amnion and allantois, in the f week. (After Krause.) The amnion (*w*) lies pretty close to the body. greater part of the yelk-sac (*d*) has been torn away. Behind this the tois appears as a small pear-shaped bladder. Arms (*f*) and legs (*b* already commenced: *v*, fore-brain; *z*, twixt-brain; *m*, mid-brain; *h*, brain; *n*, after-brain; *a*, eye; *k*, three gill-arches; *c*, heart; *s*, tail.

ıd is the intestinal-glandular layer. The outer stratum nsists of lighter, smaller cells, and is the intestinal fibrous-yer. The cavities of the mouth and the anus are the only ceptions to this, because they originate from the outer in. The inner cell-coating of the entire mouth-cavity is erefore furnished, not by the intestinal glandular-layer, ıt by the skin-sensory layer, and its muscular lower layer, ıt by the intestinal-fibrous layer, but by the skin-fibrous yer. This is equally true of the wall of the anal cavity late V. Fig. 15).

If the question be asked, what relation these component rm-layers of the primitive intestinal wall bear to the finitely varied tissues and organs which we afterwards ıd in the developed intestine, the answer is extremely mple. The relations of these two layers to the formation ıd differentiation of the tissues of the intestinal canal with l its parts, may be condensed into a single sentence: The testinal epithelium, that is, the inner, soft cell-stratum hich coats the cavities of the intestinal canal and of all its pendages, and which directly accomplishes the nutritive ocess, develops solely from the intestinal-glandular yer; on the contrary, all other tissues and organs belong-g to the intestinal canal and its appendages, proceed from e intestinal-fibrous layer. From this latter, therefore, iginates the entire outer covering of the intestinal tube ıd its appendages; the fibrous connective tissue and the nooth muscles which compose its fleshy skin; the carti-ges which support these, for example, the cartilage of the rynx and of the trachea; the numerous blood and lymph ssels which absorb nutrition from the wall of the intestine; short, everything belonging to the intestine, with the

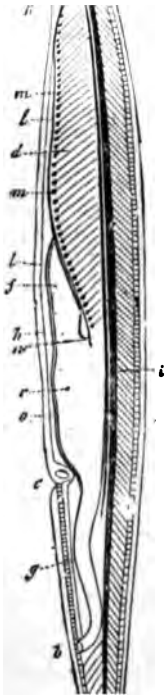
exception of the intestinal epithelium. From the int fibrous layer originates also the entire mesentery v the adjacent parts, the heart, the large blood-vessel body, etc. (Plate V. Fig. 16).

Let us now turn aside for a moment from this rudimentary intestine of Mammals, in order to ins comparison between it and the intestinal canal c lower Vertebrates and Worms, which we have lea recognize as the ancestors of Man. In the simplest (worm, or Turbellaria (*Rhabdocœlum*, Fig. 280), we very simple intestinal form. As in the gastrula, th tine in these Worms is a simple pouch with a singl ing, which latter acts both as mouth and anus (*m* intestinal pouch has, however, differentiated into t tions, an anterior throat-intestine (*sd*) and a p stomach-intestine (*d*). This differentiation become important in the Ascidia (Fig. 281) and in the Am (Fig. 282), which connects the Worms with the Vert In these two animal forms the intestine is ess identical; the anterior portion forms the respirato intestine, the posterior forms the digestive stomac tine. In both it develops, palingenetically, directly f primitive intestine of the gastrula (Plate XI. Figs. But the original mouth-opening of the gastr the primitive mouth, afterwards closes, and in its formed the later anus. In the same way, the opening of the Amphioxus and of the Ascidian is formation, as is the mouth-opening of Man, and ge of all Skulled Animals (*Craniota*). The secondary tion of the mouth of the Lancelet is connected, as conjectured with some probability, with the forma

the gill-openings, which appear directly behind it on the intestine. The front portion of the intestine has thus

FIG. 280.—A simple Gliding Worm (*Rhabdocœlum*): *m*, mouth; *sd*, throat-epithelium; *sm*, throat muscle-mass; *d*, stomach-intestine; *nc*, renal ducts; *f*, ciliated outer-skin; *nm*, openings of the latter; *au*, eye; *no*, nose-pit.

FIG. 281.—Structure of an Ascidian (seen from the left side, as in Plate XI. Fig. 14). The dorsal side is turned toward the right, the ventral side to the left; the mouth-opening (*o*) is above; at the opposite, tail end, the ascidian has become adherent. The gill-intestine (*br*), perforated by many openings, extends into the stomach-intestine. The terminal intestine opens through the anus (*a*) into the gill-cavity (*cl*), from which the excrement is passed out with the respirated water through the gill-pore, or cloaca opening (*a'*); *m*, mantle. (After Gegenbaur.)



the tribal history of Vertebrates.

The most important proces
with in the further ontogenetic de
of the intestinal canal in the hum
is the origin of the gill-opening
head of the human embryo, the
throat very early unites with the
of the body, and four openings
on the right and left sides of
behind the mouth, and these le
from without into the throat-cavi
openings are the gill-openings, a
titions separating them are the
(Figs. 116–118, vol. i. p. 356;
and V., Fig. 15, *ks*). These emb
mations are very interesting; for

**Fig. 282.—Lancelet (*Amphioxus lance*
the natural size, seen from the left si
tudinal axis is perpendicular, the mou
the tail end below (as in Plate XI. Fig. 1**

=produce, in accordance with the fundamental principle of iogeny, the same process which was originally of the reatest importance to the development of the whole verte-rate tribe. This process was the differentiation of the ntestinal canal into two sections: an anterior, respiratory art, the gill-intestine, which serves only for breathing, nd a posterior, digestive part, the stomach-intestine, which erves only for digestion. As we meet with this very haracteristic differentiation of the intestinal tube into two, hysiologically, very distinct main sections, not only in he Amphioxus, but also in the Ascidian and the Appen-icularia, we can safely conclude that it also existed in ur common ancestors, the Chorda Animals (*Chordonia*), specially as even the Acorn Worm (*Balanoglossus*) has t (Fig. 186, p. 86). All other Invertebrate Animals are ntirely without this peculiar arrangement.

The number of the gill-openings is still very large in the Amphioxus, as in Ascidians and in the Acorn Worm. In he Skulled Animals it is, on the contrary, very much essened. Fishes mostly have from four to six pairs of gill-openings. In the embryos of Man and the higher Verte-brates also, only three or four pairs are developed, and these appear at a very early period. The gill-openings are perma-nent in Fishes, and afford a passage to the water which has been breathed in through the mouth (Figs. 191, 192, p. 113; Plate V. Fig. 13, *ks*). On the other hand, the Amphibians lose them partially, and all the higher Vertebrates entirely. In the latter, only a single vestige of the gill-openings remains, the remnant of the first gill-opening. This changes into a part of the organ of hearing; from it originates the outer ear-canal, the tympanic cavity, and the Eustachian tube.

TABLE XXXVI.

Systematic Survey of the Development of the Human Intestinal

N.B.—The parts marked thus † are processes from the intestina

I. First main section of the **Intestinal System**: the Respiratory Intestine (Gill Intestine). PNEOGASTER. (*Tractus respiratorius.*)	1. Mouth-cavity (*Cavum oris*)	Mouth-opening	*Rima oris*
		Lips	*Labia*
		Jaws	*Maxillæ*
		Teeth	*Dentes*
		Tongue	*Lingua*
		Tongue bone	*Os hyoides*
		† Salivary glands	*Glandulæ sali*
		Soft palate	*Velum palatin*
		Uvula	*Uvula*
	2. Nose-cavity (*Cavum nasi*)	Nose canal	*Meatus nariu*
		† Jaw cavities	*Sinus maxill*
		† Frontal cavities	*Sinus frontal*
		† Ethmoid cavity	*Sinus ethmoid*
	3. Throat-cavity (*Cavum pharyngis*)	Isthmus of the throat	*Isthmus fauci*
		Tonsils	*Tonsillæ*
		Pharynx	*Pharynx*
		† Eustachian tube	*Tuba Eustach*
		† Tympanic cavity	*Cavum tympa*
		† Brain-appendage	*Hypophysis*
		† Thyroid gland	*Thyreoidea*
	4. Lung-cavity (*Cavum pulmonis*)	† Larynx	*Larynx*
		† Windpipe	*Trachea*
		† Lungs	*Pulmones*
II. Second main section of the **Intestinal System**: Digestive Intestine (Stomach Intestine). PEPTOGASTER. (*Tractus digestivus.*)	5. Anterior Intestine (*Prosogaster*)	Gullet	*Œsophagus*
		Stomach-opening	*Cardia*
		Stomach	*Stomachus*
		Stomach exit	*Pylorus*
	6. Central Intestine (*Mesogaster*)	Gall-intestine	*Duodenum*
		† Liver	*Hepar*
		† Pancreas	*Pancreas*
		Empty intestine	*Jejunum*
		(† Yelk-sac, or navel-bladder)	(*Vesicula um lis*)
		Crooked intestine	*Ileum*
	7. Posterior Intestine (*Epigaster*)	Large intestine	*Colon*
		† Blind intestine	*Cæcum*
		† Vermiform process of the cœcum	*Processus formis*
		Rectum	*Rectum*
		Anal opening	*Anus*
	8. Urinary Intestine (*Urogaster*)	(† Primitive urinary sac	*Allantois*)
		† Urinary tube	*Urethra*
		† Urinary bladder	*Urocystis*

ıave already considered this remarkable formation, and ›nly call attention once more to the interesting fact that human middle and external ear is the last remnant ıe gill-opening of a Fish. The gill-arches, also, which ·ate the gill-openings, develop into very various parts. ishes they remain permanently as gill-arches, carrying ·espiratory gill-tufts; so also in the lowest Amphibia; n the higher Amphibia they undergo various modifica- in the course of development, and in all the three ·r vertebrate classes, thus also in Man, the tongue-bone *yoides*) and the bonelets of the ear originate from the ırches. (Cf. Plates VI. and VII.)

'rom the first gill-arch, from the centre of the inner ce of which the muscular tongue grows, proceeds rudimentary jaw-skeleton; the upper and lower jaws h enclose the cavity of the mouth and carry the ı. The Acrania and Monorhina are entirely destitute ıese important parts. They first appear in the genuine es, and have been transmitted by these to the higher ebrates. The original formation of the human mouth- ·ton, of the upper and lower jaws, can thus be traced to the earliest Fishes, from which we have inherited ı. The teeth originate from the outer skin-covering ·h covers the jaws; for, as the formation of the whole th-cavity takes place from the outer germ-layer, the teeth ·, of course, also have developed originally from the skin- r. This can be actually proved by close microscopic ıination of the most delicate structural features of the ı. The scales of Fishes, especially of Sharks, are, in respect, exactly similar to their teeth (Fig. 283). Thus human teeth, in their earliest origin, are modified fish-

scales.[188] On similar grounds we must regard the sali glands, which open into the mouth-cavity, as really a skin (epidermic) glands, which have not developed, lik other intestinal glands, from the intestinal-glandular l of the intestinal canal, but from the outer skin, fro horn-plate of the outer germ-layer. It is evident th the mouth develops in this way, the salivary glands be placed genetically in the same series with the s sebaceous, and milk glands of the epidermis.

FIG. 283. — Scales of a Shark (*Centrophorus calceus*). On each rhomboid bone-tablet, lying in the leather-skin, rises a small, three-cornered tooth. (After Gegenbaur.)

The human intestinal ca therefore quite as simple i original formation as the pri intestine of the gastrula. I resembles that of the lowest V It then differentiates into tw tions, an anterior gill-intestin a posterior stomach-intestin the intestinal canal of the L and the Ascidian. By the de ment of the jaws and gill- it is modified into a true intestine. Afterwards, howev gill-intestine, which is a me of the Fish-ancestors, as s entirely lost. The parts that take a wholly different form notwithstanding that the a section of our intestinal can surrenders entirely its o yet retains its physiological form of gill-intestine, it tion as a respiratory intestine; for the extreme

ing and remarkable discovery is now made that even ermanent respiratory organ of the higher Vertebrates, ir-breathing lungs, has also developed from this anterior n of the intestinal canal. Our lungs, together with vind-pipe (*trachea*) and the larynx, develop from the al wall of the anterior intestine. This entire great hing-apparatus, which occupies the greater part of hest (*thorax*) in the developed Man, is at first merely y small and simple vesicle or sac, which grows out the intestinal canal immediately behind the gills, and separates into two lateral halves (Figs., 284, *c*, 285, *c*; V. Figs. 13, 15, 16, *lu*). This vesicle occurs in all brates except in the two lowest classes, the Acrania and stomi. In the lower Vertebrates, however, it develops, nto lungs, but into an air-filled bladder of considerable occupying a great part of the body-cavity (*cœloma*), which is of quite a different significance from the . It serves, not for breathing, but as an hydrostatic ratus: for vertical swimming movements it is the ming-bladder of Fish; but the lungs of Man and of ther air-breathing Vertebrates develop from the same e bladder-like appendage of the anterior intestine, h, in Fishes, becomes the swimming-bladder.

riginally this sac also has no respiratory function, but s only as an hydrostatic apparatus, augmenting or nishing the specific gravity of the body. Fishes, in h the swimming-bladder is fully developed, are able to ress it, and thus to condense the air contained in it. air sometimes also escapes from the intestinal canal gh an air-passage which connects the swimming- er with the throat (*pharynx*), and is expelled through

the mouth; in this way the circumference of the s ming-bladder is diminished, and the fish becomes he and sinks. When the animal is again about to as the swimming-bladder is distended by remitting the

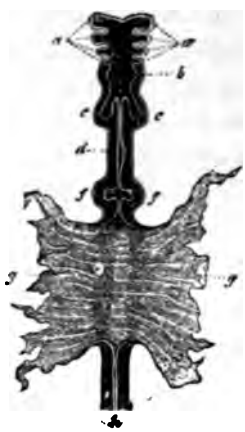


FIG. 284.—Intestine of an embryonic Dog (which is represented 137, vol. i. p. 382; after Bischoff), from the ventral side: *a*, gill-arche pairs); *b*, rudimentary throat and larynx; *c*, lungs; *d*, stomach; *f*, li walls of the opened yelk-sac, into which the central intestine oper wide aperture; *h*, rectum.

FIG. 285.—The same intestine, seen from the right side: *a*, lu stomach; *c*, liver; *d*, yelk-sac; *e*, rectum.

pressing force. This hydrostatic apparatus begins transformed into a respiratory organ in the Mud (*Dipneusta*), the blood-vessels in the wall of the ming-bladder no longer merely separating air, bu inhaling fresh air, which has come in through th passage. This process is fully developed in all Amp The original swimming-bladder here generally beco

lung, and its air-passage a wind-pipe. The amphibian lung has been transmitted to the three higher vertebrate classes, and even in the lowest Amphibia the lung on either side is as yet a very simple, transparent, thin-walled sac—as, for instance, in our common Water-Newts, or Tritons, and very like the swimming-bladder of Fishes. The Amphibia have, it is true, two lungs, a right and a left; but in many Fishes also (in the ancient Ganoids) the swimming-bladder is double, the organ being divided into a right and a left half. On the other hand, the lung of the Ceratodus is single (p. 119). The earliest rudiment of the lung in the human embryo and in the embryo of all higher Vertebrates is also a simple, single vesicle, which does not separate till afterwards into a pair of halves—the right and the left lung. At a later period, the two vesicles grow considerably, occupy the greater part of the chest cavity, and lie one on each side of the heart; even in Frogs we find that the simple sac, in the course of its development, is transformed into a spongy body of a peculiar, froth-like texture. This lung-tissue develops as a tree-like, branched gland, bearing berry-like appendages. The process by which the lung-sac was attached to the anterior intestine, which was originally very short, lengthens, by simple growth, into a long thin tube; this tube is the wind-pipe (*trachea*); it opens above into the throat (*pharynx*), and below divides into two branches which pass into the two lungs. In the wall of the wind-pipe ring-shaped cartilages develop, which keep the whole distended; at the upper end of this wind-pipe, below its entrance into the throat, the larynx, the organ of voice and speech, develops. The larynx occurs even in Amphibia in very various stages of development, and with the aid of

Comparative Anatomy we can trace the progressive development of this important organ from its very simple rudiment in the lower Amphibia up to the complex and vocal apparatus represented by the larynx of Birds and Mammals.

Though these organs of voice, speech, and air-respiration develop so differently in the various higher Mammals, they yet all arise from the same simple original rudiment—from a vesicle which grows out of the wall of the anterior intestine. We have thus satisfied ourselves of the interesting fact that both the respiratory apparatus of Vertebrates develop from the fore part of the intestinal canal; first, the primary and more primitive water-respiring apparatus, the gill-body, which is altogether lost in the three higher vertebrate classes; and, afterwards, the secondary and more recent air-breathing apparatus, which acts in Fishes only as a swimming-bladder, but as a lung from the Dipneusta upwards.

We must say a few words about an interesting rudimentary organ of the respiratory intestine, the thyroid gland (*thyreoidea*), the large gland situated in front of the larynx, and below the so-called "Adam's apple," and which, especially in the male sex, is often very prominent; it is produced in the embryo by the separation of the lower wall of the throat (*pharynx*). This thyroid gland is of no use whatever to man; it is only æsthetically interesting, because in certain mountainous districts it has a tendency to enlarge, and in that case it forms the "goitre" which hangs from the neck in front. Its dysteleological interest is, however, far higher; for as Wilhelm Müller of Jena has shown, this useless and unsightly organ is the last remnant of the "hypobranchial groove," which we have

eady considered, and which, in the Ascidia and in the nphioxus, traverses the middle of the gill-body, and is of eat importance in conducting the food into the stomach ol. i. p. 420; Plate XI. Figs. 14–16, *y*).[189]

The second main section of the intestinal canal, the mach or digestive intestine, undergoes modifications no s important than those affecting the first main section. tracing the further development of this digestive section the intestinal tube, we again find a very complex and nposite organ eventually produced from a very simple liment. For the sake of rendering the matter more elligible, we may distinguish the digestive intestine o three parts: the fore intestine (with the gullet and mach); the middle intestine, the gall-intestine (with the er and pancreas); the empty intestine (*jejunum*), and oked intestine (*ileus*); and the hind intestine (large estine and rectum). Here we again find protuberances appendages of the originally simple intestinal tube ich change into very various structures. We have eady discussed two of these appendages—the yelk-sac, ich protrudes from the middle of the intestinal tube ig. 286, *c*), and the allantois, which grows out of the t portion of the pelvic intestine as a large sac-like tuberance (*u*). The protuberances from the middle the intestine are the two great glands which open o the duodenum, the liver (*h*) and the ventral salivary nd.

Immediately behind the bladder-like rudiment of the gs (Fig. 286, *l*) comes that portion of the intestinal tube ich forms the most important part of the digestive aratus, viz., the stomach (Figs. 284, *d*, 285, *b*). This sac-

shaped organ, in which the food is especially dissolved and digested, is not so complex in structure in the lower Vertebrates as in the higher. Thus, for instance, in many Fishes it appears as a very simple spindle-shaped expansion at the

FIG. 286.—Longitudinal section through an embryonic Chick on the fifth day of incubation: *d*, intestine; *o*, mouth; *a*, anus; *l*, lungs; *h*, liver; *g*, mesentery; *v*, auricle of heart; *k*, ventricle of heart; *b*, arterial arches; *l*, aorta; *c*, yelk-sac; *m*, yelk-duct; *u*, allantois; *r*, stalk of allantois; *n*, amnion; *w*, amnion-cavity; *s*, serous membrane. (After Baer.)

beginning of the digestive section of the intestine, which latter passes from front to rear in a straight line under the spinal column in the central plane of the body. In Mammals the rudiment of this organ is as simple as it that is permanently in Fishes; but at a very early period the various parts of the stomach-sac begin to develop unequally. As the left side of the spindle-shaped pouch grows much more vigorously than the right, and as, at the same time

occurs a considerable obliquity of its axis, it soon
es an oblique position. The upper end lies more to
t and the lower end more
right. The anterior end
is so as to form the long
canal of the gullet
agus); below the latter,
lind-sac of the stomach
us) bulges out to the left,
ius the later form of the
h is gradually developed
87, *e*; Fig. 275, p. 317). The
which was originally verti-

287.—Human embryo of five
from the ventral side; opened
d). The breast wall, abdominal
d liver, have been removed. 3,
nasal process; 4, upper jaw; 5,
aw; *z*, tongue; *v*, right, *v'*, left
e of heart; *o'*, left auricle of
b, origin of aorta; *b' b'' b'''*, 1st,
d aorta-arches; *c c' c''*, hollow
e, lungs (*y*, lung-arteries); *r*,
; *m*, primitive kidneys (*j*, left
in; *s*, pylorus; *a*, right yelk-
n, navel-artery; *u*, navel-vein);
-duct; *i*, terminal intestine; 8,
fore-limb 9', hind-limb. (After

ow inclines from a higher point on the left to a lower
e right, and continually acquires a more transverse
ion. In the outer stratum of the stomach-wall, and
the intestinal-fibrous layer, develop the strong muscles
perform the powerful digestive movements. In

the inner stratum, on the contrary, innumerable minute glands develop from the intestinal-glandular layer. These are the peptic glands, which supply the most important digestive fluid—the gastric juice. At the lower extremity of the pouch of the stomach a valve develops, which, as the pylorus, separates the stomach from the small intestine (Fig. 275, *d*).

The disproportionately long middle intestine, or small intestine, now develops below the stomach. The development of this section is very simple, and is essentially caused by a very rapid and considerable longitudinal growth. Originally this section is very short, straight, and simple; but immediately below the stomach a horseshoe bend, or loop, begins to appear at a very early period in the intestinal canal, simultaneously with the separation of the intestinal tube from the yelk-sac and with the development of the mesentery. (Cf. Plate V. Fig. 14, *g*, and Fig. 136, vol. i. p. 381.) Before the abdominal wall closes, a horseshoe-shaped loop of intestine (Fig. 136, *m*) protrudes from the ventral opening of the embryo, and into the curve of this the yelk-sac or navel-bladder opens (*n*). The thin, delicate membrane which secures this intestinal loop to the ventral side of the vertebral column, and occupies the inside of this horseshoe curve, is the first rudiment of the mesentery (Fig. 286, *g*). The most prominent part of the loop into which the yelk-sac opens (Fig. 287, *x*), and which is afterwards closed by the intestinal navel, represents that part of the small intestine which is afterwards called the crooked intestine (*ileum*). Soon a very considerable growth of the small intestine is observable; and in consequence, this part has to coil itself in many loops. The various parts of the small intestine which we

have yet to distinguish differentiate later in a very simple way; these are the gall-intestine (*duodenum*), which is next to the stomach, the long empty intestine (*jejunum*) which succeeds, and the last section of the small intestine, the crooked intestine (*ileum*).

The two large glands which we have already named, the liver and the ventral salivary gland, grow out, as protuberances, from the gall-intestine, or duodenum. The liver first appears in the form of two small sacs, situated right and left just behind the stomach (Figs. 284, *f*, 285, *c*). In many low Vertebrates the two livers remain quite separate for a long time (in the Myxinoides for life), and coalesce only imperfectly. In higher Vertebrates, on the other hand, the two livers coalesce more or less completely at an early period, and constitute one large organ. The intestinal-glandular layer, which lines the hollow, pouch-like rudiment of the liver, sends a number of branched processes into the investing intestinal-fibrous layer; as these solid processes (rows of gland-cells) again branch out, and as their branches coalesce, the peculiar netted structure of the developed liver is produced. The liver-cells, as the secreting organs which form the bile, all originate from the intestinal-glandular layer. The fibrous mass of connective tissue, which joins this great cellular network into a large compact organ, and which invests the whole, comes, on the other hand, from the intestinal-fibrous layer. From the latter originate also the great blood-vessels which traverse the entire liver, and the innumerable netted branches of which are interlaced with the network of the liver-cells. The gall-ducts, which traverse the entire liver, collecting the bile and discharging it into the intestine, originate as intercellular passages along

the axis of the solid cell-cords; they all discharge i
two primitive main gall or biliary ducts, which o
from the base of the two original protuberances
intestine. In Man, and in many other Vertebrate
two ducts afterwards unite, and form one simple g
which discharges into the ascending portion of t
intestine. The gall bladder originates as a hollo
tuberance of the right primitive liver duct. The
of the liver is at first exceedingly rapid; in the
embryo, even in the second month, it attains such
sions that during the third month it occupies by
largest part of the body-cavity (Fig. 288). At firs

FIG. 288.—Chest and abdominal visc
human embryo of twelve weeks, in nat
(After Koelliker.) The head is omitted;
and abdominal walls removed. The gre
of the abdominal cavity is occupied by
from an opening in the centre of which t
intestine (*cæcum*, *v*), with the worm ap
protrudes. Above the diaphragm the
visible in the centre, with the small lung
right and left.

halves are equally well developed; afterwards the l
lies considerably behind the right. In consequence
asymmetrical development and alteration in the posi
the stomach and other abdominal viscera, the whole
liver is eventually forced over on to the right side. Al
the growth of the liver is, afterwards, not so excessiv
at the end of gestation, it is comparatively much la
the embryo than in the adult. In the latter, its

a proportion to that of the whole body is as 1 : 36; in the ormer, as 1 : 18. The physiological significance of the liver uring embryonic life—which is very great—depends espe-ially on the part it plays in the formation of blood, and ess on its secretion of bile.

From the gall-intestine, immediately behind the liver, grows another large intestinal gland, the ventral-salivary gland, or pancreas. This organ, which occurs only in Skulled Animals, also develops as a hollow sac-shaped protuberance of the intestinal wall. The intestinal-glan-dular layer of the latter sends out branching shoots, which afterwards become hollow. The ventral-salivary gland, just like the salivary glands of the mouth, develops into a large and very complex gland shaped like a bunch of grapes. The outlet of this gland (*ductus pancreaticus*), through which the pancreatic juice passes into the gall-intestine, seems to be at first simple and single; afterwards it is often double.

The last section of the intestinal tube, the terminal intestine or large intestine (*epigaster*), in mammalian embryos, is, at first, a very simple, short, and straight tube, opening posteriorly through the anus. In the lower Ver-tebrates it retains this form throughout life. In Mammals, on the other hand, it grows to a considerable size, coils, and differentiates into different sections, of which the foremost and longest is called the colon, the shorter and hinder the rectum. At the commencement of the former a valve (*valvula Bauhini*) forms, which divides the large intestine from the small intestine; behind appears a pouch-like protuberance, which grows larger and becomes the blind-intestine (*cæcum*) (Fig. 288, *v*). In plant-eating Mammals

this becomes very large, while in those which eat flesh remains very small, or is entirely aborted. In Man, as most Apes, the beginning of the blind intestine al becomes wide; its blind end remains very narrow, afterwards appears only as a useless appendage of former. This "vermal appendage" is interesting in teleology as a rudimentary organ. Its only importanc Man consists in the fact that now and then a raisin-st or some other hard, indigestible particle of food beco lodged in its narrow cavity, causing inflammation suppuration, and, consequently, killing individuals ot wise perfectly healthy. In our plant-eating ancestors rudimentary organ was larger, and was of physiolog value.

Finally, we must mention another important append of the intestinal tube; this is the urinary bladder (*cystis*) with the urinary tube (*urethra*), which in deve ment and in morphological character belong to the intest system. These urinary organs, which act as receptacles excretory passages for the urine secreted by the kidn originate from the inner part of the allantois-stalk. allantois develops, as a sac-like protuberance, from anterior wall of the last section of the intestine (Fig. 286 In the Dipneusta and Amphibia, in which this blind first appears, it remains within the body-cavity (*cœlon* and acts entirely as a urinary bladder. In all Amniota the other hand, it protrudes considerably out of the bo cavity of the embryo, and forms the large embry "primitive urinary sac," which, in higher Mammals, fo the placenta. At birth this is lost; but the long allant stalk (*r*) remains, its upper portion forming the central n

band of the urinary vesicle (*ligamentum vesico-umbilicale medium*), a rudimentary organ which extends as a solid cord from the top of the urinary bladder to the navel. The lower part of the allantois-pedicle (the "*urachus*") remains hollow, and forms the urinary bladder. At first, in Man, as in the lower Vertebrates, this organ discharges into the last section of the posterior intestine, and there is, therefore, a true "cloaca," receiving both urine and excrement; but, among the Mammals, this cloaca is permanent only in the Cloacal Animals, or Monotremes, as in Birds, Reptiles, and Amphibia. In all other Mammals (*Marsupialia* and *Placentalia*) a transverse partition forms at a later period, and separates the urinary-sexual aperture in front from the anal aperture behind. (Cf. Chapter XXV.)

EXPLANATION OF PLATE I.—(FRONTISPIECE.)

DEVELOPMENT OF THE FACE.

The twelve figures in Plate I. represent the faces of four different Mammals in three distinct stages of individual evolution: MI–MIII that of Man, BI–BIII of the Bat, CI–CIII of the Cat, SI–SIII of the Sheep. The three different stages of evolution have been chosen to correspond as far as possible; they have been reduced to about the same size, and are seen from in front. In all the figures the letters indicate the same: *a*, eye; *v*, fore-brain; *m*, mid-brain; *s*, frontal process; *k*, nose-roof; *o*, upper jaw process (of the first gill-arch); *u*, lower jaw process (of the first gill-arch); *b*, second gill-arch; *d*, third gill-arch; *r*, fourth gill-arch; *g*, ear-fissure (remains of the front gill-opening); *z*, tongue. (Cf. Plates VI. and VII. Figs. 232–236, p. 243; also Figs. 123, 124, vol. i. p. 370.)

TABLE XXXVII.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN INTESTINAL SYSTEM.

I. *First Period: Intestine of Gastræa* (Figs. 274–277; Plate V. Figs. 9, 10).

The whole intestinal system is a simple pouch (primitive intestine), the simple cavity of which has one orifice (the primitive mouth).

II. *Second Period: Intestine of the Scolecida* (Plate V Fig. 11).

The simple intestinal tube widens in the middle into the stomach, and acquires, at the end opposite to the primitive mouth, a second opening (primitive anus); as in the lower Worms.

III. *Third Period: Intestine of Chorda Animals* (Fig. 281; Plate V. Fig. 12).

The intestinal tube differentiates into two main sections—the respiratory intestine with gill-openings (gill-intestine) in front, the digestive intestine with stomach-cavity (stomach-intestine) behind; as in Ascidia.

IV. *Fourth Period: Intestine of Skull-less Animals (Acrania)* (Fig. 282; Plate XI. Fig. 15).

The gill-streaks appear between the gill-openings of the respiratory intestine; a liver blind-sac grows from the stomach-pouch of the digestive intestine; as in the Amphioxus.

V. *Fifth Period: Intestine of Cyclostoma* (Plate XI. Fig. 16).

The thyroid gland develops from the ciliated groove on the base of the gills (hypobranchial groove). A compact liver-gland develops from the liver blind-sac.

VI. *Sixth Period: Intestine of Primitive Fishes* (p. 114).

Cartilaginous gill-arches appear between the gill-openings. The foremost of these form the lip-cartilages and the jaw-skeleton (upper and lower jaw). The swimming-bladder grows from the pharynx. The ventral-salivary gland appears near the liver, as in Selachii.

VII. *Seventh Period: Intestine of Dipneusta* (p. 118).

The swimming-bladder modifies into the lungs. The mouth-cavity becomes connected with the nose-cavity. The urinary bladder grows from the last section of the intestine, as in Lepidosiren.

VIII. *Eighth Period: Intestine of Amphibia* (p. 126).

The gill-openings close. The gills are lost. The larynx originates from the upper end of the trachea.

IX. *Ninth Period: Intestine of Monotremes* (p. 145).

The primitive mouth and nasal cavity is separated by the horizontal palate-roof into the lower mouth-cavity (food passage) and the upper nose-cavity (air passage); as in all Amnion Animals.

X. *Tenth Period: Intestine of Marsupials* (p. 149).

The existing cloaca is separated by a partition wall into an anterior urinary-sexual aperture and a posterior anal aperture.

XI. *Eleventh Period: Intestine of Catarhine Apes* (p. 176).

All parts of the intestine, and especially the teeth-apparatus, acquire the characteristic development common to Man and Catarhine Apes.

CHAPTER XXIV.

DEVELOPMENT OF THE VASCULAR SYSTEM.

Application of the Fundamental Law of Biogeny.—The Two Sides.—Heredity of Conservative Organs.—Adaptation of Progressive Organs.—Ontogeny and Comparative Anatomy complementary of each other.—New "Theories of Evolution" of His.—The "Envelope Theory" and the "Waste-rag Theory."—Main Germ and Supplementary Germ.—Formative Yelk and Nutritive Yelk.—Phylogenetic Origin of the latter from the Primitive Intestine.—Origin of the Vascular System from the Vascular Layer, or Intestinal-fibrous Layer.—Phylogenetic Significance of the Ontogenetic Succession of the Organ-systems and Tissues.—Deviation from the Original Sequence; Ontogenetic Heterochronism.—Covering Tissue.—Connective Tissue.—Nerve-muscle Tissue.—Vascular Tissue.—Relative Age of the Vascular System.—First Commencement of the Latter; Cœloma.—Dorsal Vessel and Ventral Vessel of Worms.—Simple Heart of Ascidia.—Atrophy of the Heart in the Amphioxus.—Two-chambered Heart of the Cyclostoma.—Arterial Arches of the Selachii.—Double Auricle in Dipneusta and Amphibia.—Double Ventricle in Birds and Mammals.—Arterial Arches in Birds and Mammals. Germ-history (Ontogeny) of the Human Heart.—Parallelism of the Tribal-history (Phylogeny).

"Morphological comparison of the adult conditions should naturally precede the study of the earliest conditions. Only in this way can the investigation of the history of development proceed in a definite direction; it is thus provided, as it were, to see each step in the formative process in its true relation with the condition which is finally to be reached. Treatment of the history of development without preparatory study is only too

likely to lead to groping in the dark; and it not unfrequently leads to the most unfortunate results—far inferior to those which might be established beyond question without any study of the history of development."—ALEXANDER BRAUN (1872).

IN applying to Organogeny the fundamental law of Biogeny, we have already afforded some conception of the degree in which we may follow its guidance in the study of tribal history. The degree differs greatly in the different organ-systems; this is so, because the capacity for transmission on one side, and the capacity for modification on the other, vary greatly in the different organs. Some parts of the body cling tenaciously to the inherited germ-history; and, owing to heredity, accurately retain the mode of evolution inherited from primæval animal ancestors; other parts of the body, on the contrary, exhibit very small capacity for strict heredity, and have a great tendency to assume new kenogenetic forms by adaptation, and to modify the original Ontogeny. The former organs represent, in the many-celled community of the human organism, the constant or conservative; the latter, on the contrary, the changeable or progressive element of evolution. The mutual interaction of both elements determines the course of historical evolution.

Only to the conservative organs, in which Heredity preponderates over Adaptation, in the course of tribal evolution, can we directly apply the Ontogeny to the Phylogeny, and can infer, from the palingenetic modification of the germ-forms, the primæval metamorphosis of the tribal forms. In the progressive organs, on the contrary, in which Adaptation has acquired the ascendency over Heredity, the original course of evolution has, usually, been so changed,

vitiated, and abbreviated, in the course of time, that
can gain but little certain information as to the trib
history from the kenogenetic phenomena of their ge
history. Here, therefore, Comparative Anatomy must co
to our help, and it often affords much more important a
trustworthy disclosures as to Phylogeny than Ontog
is able to impart. It is, therefore, most important, if
fundamental law of Biogeny is to be correctly and critic
applied, to keep its two sides continually in view. '
first half of this fundamental law of evolution enables u
use Phylogeny, as it shows us how to gain an approxim
knowledge of the history of the tribe from that of
germ: the germ-form reproduces, by Heredity, the co
sponding tribal form (Palingenesis). The other half
the law, however, limits this guiding principle, and c
attention to the foresight with which it must be employ
it shows us that the original reproduction of the Phylog
in the Ontogeny has been in many ways altered, vitia
and abbreviated, in the course of millions of years. '
germ-form has deviated, by Adaptation, from the co
sponding tribal form (Kenogenesis); the greater this de
tion, the more are we compelled to employ Compara
Anatomy in the study of Phylogeny.

Perhaps in no other system of organs of the human b
is this so greatly the case as in the vascular system (
cular, or circulatory apparatus), the development of wl
we will now examine. If we attempted to infer
original structural features of our older animal ances
solely from the phenomena which the individual deve
ment of these organ-systems, in the embryo of Man an
other high Vertebrates, exhibit, we should obtain wh

erroneous views. By many influential embryonic adaptations, among which the development of an extensive nutritive yelk must be regarded as the most important, the original course of development of the vascular system has been so altered, vitiated, and abbreviated, in the higher Vertebrates, that no, or very little, trace of many of the most important phylogenetic features are retained in the Ontogeny. Such explanation as is afforded by the latter would be entirely useless to us if Comparative Anatomy did not lend its aid, and afford us the clearest guidance in our search for tribal history.

Comparative Anatomy is, therefore, especially important in helping us to understand the vascular system, and, equally, the skeleton system, so that, without its guidance, it is unsafe to take a single step in this difficult field. Positive proof of this assertion can be gained by studying the complex vascular system as explained in the classical works of Johannes Müller, Heinrich Rathke, and Karl Gegenbaur. An equally strong negative proof of the assertion is afforded by the ontogenetic works of Wilhelm His, an embryologist of Leipsic, who has no conception of Comparative Anatomy, nor consequently, of Phylogeny. In 1868, this industrious but uncritical worker published certain comprehensive "Studies of the First Rudiment of the Vertebrate Body," which are among the most wonderful productions in the entire literature of Ontogeny. As the author hopes to attain a "mechanical" theory of development by means of a most minute description of the germ-history of the Chick alone, without the slightest reference to Comparative Anatomy and Phylogeny, he falls into errors which are unparalleled in the whole literature of

Biology, rich as this unfortunately is in errors. Only in magnificent germ-history of the Bombinator by Alexa Goette is incomprehensible nonsense and derision of e reasonable causal connection in evolution more nakedly forth. (Cf. vol. i. pp. 65, 66.) His announces, as the result of his investigations, "that a comparatively si law of growth is the only essential in the first proce evolution. All formation, whether it consist in fissio layers, or in the formation of folds, or in complete arti tion, results from this fundamental law." Unfortun the author does not say in what this all-embracing "la growth" really consists; just like other opponents of theory of descent who substitute a great "law of evolut without telling anything of its nature. From the stud the ontogenetic works of His, on the otl er hand, it becomes evident that he conceives form-construc "Mother Nature" merely as a kind of clever dressma by cutting out the germ-layers in various ways, by b ing, folding, pulling, and splitting them, this clever se stress easily brings into existence the various form animal species, by "development" (!). The bendings foldings especially play the most important part. Not the differentiation of head and trunk, of right and lef central stem and periphery, but also the rudiment of limbs, as also the articulation of the brain, the sense-org the primitive vertebral column, the heart, and the ear intestines, can be shown, with convincing necessity (!) t mechanical results of the first development of folds. I grotesque is the mode in which the dressmaker proceed forming the two pairs of limbs. Their first form is de mined by the crossing of four folds bordering the b

like the four corners of a letter." Yet this wonderful envelope theory" of the vertebrate limbs is surpassed by he "waste-rag theory" (Höllen-lappen Theorie) which His ives of the origin of the rudimentary organs: "Organs like the hypophysis and the thyroid gland) to which no hysiological part has yet been assigned, are embryonic emnants, comparable to the clippings, which in the cutting f a dress cannot be entirely avoided, even by the most conomical use of the material" (!). Nature, therefore, in utting out, throws the superfluous rags of tissue into the vaste heap. Had our skull-less ancestors of the Silurian ge had any presentiment of such aberrations of intellect f their too speculative human descendants, they would ertainly have preferred relinquishing possession of the hypobranchial groove on the gill-body, instead of transmitting it to the extant Amphioxus, and of leaving a remnant of it to us, in the equally unsightly as useless thyroid gland. (Cf. p. 336).

It will probably be thought that the ontogenetic "discoveries" of His, which appear in a doubly comical light in consequence of the accompanying display of mathematical calculations, can only have occasioned momentary amusement in critical scientific circles. Far from it! Immediately after their appearance, they were not only much praised as the beginning of a new "mechanical" era in Ontogeny, but they have even yet numerous admirers and adherents, who seek to spread the scientific errors of His as far as possible. On this account, I have felt myself obliged to point out emphatically the complete falsity of these views. The vascular system affords especial occasion for this; for among the most important advances which His

claims to have caused by his new conception of g
history, is, according to him, his discovery that "the b
and tissue of the connective substance" (that is to say,
greatest part of the vascular system) "do not originate
the two primary germ-layers, as do all the other or
but from the elements of the white yelk." The b
is designated as "supplementary yelk, or parablast,"
distinguish it from the "main-germ, or archiblast"
germ-disc composed of the two primary germ-layers).

The whole of this artificial development theory of
and above all the unnatural distinction between the su
mentary and the main germ, collapses like a card h
when the Anatomy and Ontogeny of the Amphioxus,
invaluable lowest Vertebrate, is contemplated, which
can elucidate the most difficult and darkest features i
development of the higher Vertebrates, and thus a
Man. The gastrula of the Amphioxus alone overth
the whole artificial theory; for this gastrula teach
that all the various organs and tissues of complete V
brates originally developed entirely from the two pri
germ-layers. The developed Amphioxus, like all
Vertebrates, has a differentiated vascular system
a skeleton of "connective substance tissues" exte
throughout its body, and yet there is in this case no
plementary germ" from which these tissues can ori
thus, contrasting with the other tissues.

The larvæ of the Amphioxus, arising from the or
bell-gastrula (*archigastrula*), in its further develop
throws the most important rays of light also upon the
cult history of development of the vascular system. I
first place, it answers the very important question,

we have already frequently indicated, as to the origin of the four secondary germ-layers; it clearly shows that the skin-fibrous layer originates from the exoderm, the intestinal-fibrous layer, on the contrary, in an analogous manner, from the entoderm of the gastrula; the cavity thus caused between the two fibrous layers is the first rudiment of the body-cavity, or the cœlom (Figs. 50, 51, vol. i. p. 236). As the Amphioxus larva thus shows that the fission of the layers is the same in the lowest Vertebrates as in the Worms, it at the same time represents the phylogenetic connection between the Worms and the higher Vertebrates. As, moreover, the primitive vascular stems in the Amphioxus originate in the intestinal wall, and in this, as in the embryos of all other Vertebrates, proceed from the intestinal-fibrous layer, proof is afforded us that the earlier embryologists were right in calling the latter the vascular layer. Finally, the Comparative Ontogeny of the different vertebrate classes further convinces us that the vascular layer is originally everywhere the same. The vascular system in Man, as in all Skulled Animals, forms a complex apparatus of cavities, which are filled with juices, or fluids, containing cells. The vessels play an important part in the nourishment of the body; some of them conduct the nutritive blood fluid round in the different parts of the body (blood-vessels); some collect the wasted juices and discharge them from the tissues (lymph-vessels). With the latter, the great "serous cavities" are also connected, especially the body-cavity, or cœloma. The heart, acting as a centre of motion for the regular circulation of the juices, is a strong muscular pouch, which contracts in regular pulsations, and is provided with valves, like those of a pump apparatus.

This constant and regular circulation of the blo
makes the complex change of substance with tl
animals possible.

Important as is the vascular system in the mor
developed and differentiated animal body, it is not,
an apparatus as indispensable to animal life as is
supposed. In the older theory of medicine the b
regarded as the real source of life, and "humoral pa
referred most diseases to "corrupt blood-mixture."
larly, the blood plays the most important part in
vailing, obscure conception of Heredity. Just as ha
pure blood, etc., etc., are yet common phrases, so it i
believed that the transmission, by Heredity, of
morphological and physiological characters from th
to the child "lies in the blood." That this cu
notion is entirely false, is easily seen from the fa
neither in the act of procreation is the blood of the
directly transmitted to the procreated germ, nor
embryo acquire blood at an early period. As
already seen, not only the separation of the four se
germ-layers, but also the beginning of the most
tant organs, takes place, in the embryos of all Ver
before the rudiment of the vascular systems, of tl
and blood, is formed. In accordance with this ont
fact, we must, from a phylogenetic point of view, re
vascular system as the most recent, the intestinal
on the contrary, as the oldest formation of the anim
The origin of the vascular system is, at least, mu
than that of the intestinal system. If the fundame
of Biogeny is rightly appreciated, it is possible, fi
ontogenetic sequence, in which the various organs

imal body consecutively originate in the embryo, approximately to infer the phylogenetic sequence, in which these gans gradually developed, one after the other, in the cestral line of animals. In the "Gastræa theory" I made e first attempt to establish the phylogenetic significance the ontogenetic sequence of the organ-systems; but it ust be remarked that this sequence is not always identical in the higher animal tribes. In Vertebrates, and erefore also in our own ancestral line, the organ-systems ay be ranged according to age, in something like the llowing order: I. The skin-system (*A*) and the intestinal stem (*B*). II. The nerve (*C*) and muscular systems (*D*). I. The kidney system (*E*). IV. The vascular system (*F*). The skeleton system (*G*). VI. The sexual system (*H*). f. Table XXXIX., p. 367.)

In the first place, the gastrula proves that in all animals ith the exception of the Primitive Animals (*Protozoa*),—herefore, in all Intestinal Animals (*Metazoa*),—two primary rgan-systems originally arose simultaneously and first; hese were the skin-system (skin-covering) and the intesinal system (stomach-pouch). The first is represented, in ts earliest and simplest form, by the skin-layer or exoderm, he latter by the intestinal layer or entoderm of the Gastræa. As we can ascribe the same origin, and, therefore, also the ame morphological significance, to these two primary germayers in all Intestinal Animals, from the simplest Sponge o Man, the homology of these two layers seems sufficient roof of the above assumption.

Immediately after the differentiation of the two primary erm-layers, an inner or outer skeleton develops in many ower animals (*e.g.*, in Sponges, Corals, and other Plant

Animals). In the ancestors of Vertebrates, the deve
of the skeleton did not take place till much late
Chorda Animals (*Chordonia*). In them, after t
system and the intestinal system, two other organ
simultaneously arise; these are the nervous and t
cular systems. The way in which these two organ
which mutually condition each other, developed
neously and independently, in reciprocal action an
opposition to each other, was first explained by N
Kleinenberg in his excellent monograph on the H
common fresh-water Polyp.[190] In this interesti
animal, single cells of the skin-layer send fibre-sha
cesses inward, which acquire the power of contra
capacity, characteristic of the muscles, of contract
constant direction. The outer, roundish part of
derm cell remains sensitive and acts as the nervous
the inner, fibre-shaped part of the same cell becc
tractile, and, incited to contraction by the former
as the muscular element (Fig. 293). These re
neuro-muscular cells thus still unite in a single i
of the first order the functions of two organ-syste
step further; the inner, muscular half of the neuro-
cell (Fig. 293, *m*) acquires its own nucleus, and
from the outer, nervous half (*n*), and both orga
have their independent element of form. The fissi
muscular skin-fibrous layer from the nervous ski
layer in embryonic Worms confirms this importa
genetic process (Figs. 50, 51, vol. i. p. 236).

These four organ-systems, which have been m
were already in existence, when an apparatus d
tertiarily, in the human ancestral line, which,

ght, seems of subordinate significance, but which proves, by its early appearance in the animal series and in the embryo, that it must be very ancient and, consequently, of great physiological and morphological value. This is the urinary apparatus, or kidney system, the organ-system which secretes and removes the useless fluids from the body. We have already seen how soon the primitive kidneys appear in the embryo of all Vertebrates, long before any trace of the heart is discoverable. Correspondingly, we also find a pair of simple primitive kidney ducts (the so-called excretory ducts or lymphatic vessels) almost universally diffused in the Worm tribe, which is so rich in forms. Even the lowest classes of Worms, which have as yet neither body-cavity nor vascular system, are furnished with these primitive kidneys (Fig. 280, *nc*, p. 327). It was only in the fourth place, after the kidney system, that the vascular system developed in our invertebrate ancestors; this is plainly shown in the Comparative Anatomy of Worms. The lower Worms (*Acœlomi*) possess no part of the vascular system, no body-cavity, no blood, no heart, and no vessels; this is the case, for example, in the comprehensive group of the Flat Worms (*Plathelminthes*), the Gliding Worms (*Turbellaria*), the Sucking Worms (*Trematoda*), and the Tape Worms. In the higher Worms, which are therefore called Cœlomati, a body-cavity (*cœloma*), filled with blood, first begins to form; and, side by side with this, special blood-vessels then also develop. These features have been transmitted from the Cœlomati to the four higher animal tribes.

These organ-systems are common to Vertebrates and to the three higher animal tribes, the Articulated Animals

(*Arthropoda*), the Soft-bodied Animals (*Mollusca*), a
Star Animals (*Echinoderma*), and we may, therefor
that they have all acquired these, as a common inhe
from the Cœlomati; but we now meet with a
apparatus of movement, the skeleton system, which,
form, is exclusively peculiar to Vertebrates. Only th
first rudiment of this, the simple notochord, is fo
Ascidia, which are the nearest invertebrate blood-re
of Vertebrates. We infer from this, that the c
ancestors of both, the Chorda Animals, did not bra
from the Worms till a comparatively late period
notochord is, it is true, one of those organs which ap
a very early period in the vertebrate embryo; but
clearly due to an ontogenetic heterochronism, to d
ment in time in the germ-history, that is, a gradu
arrangement in the original phylogenetic sequence,
by embryonic adaptation. On Comparative Ana
grounds it may safely be assumed, that the first o
the skeleton system did not precede, but followed
the kidney system and of the vascular system, a
Ontogeny appears to indicate the contrary.

Last of all the organ-systems, the sexual system
developed, in the sixth place, in our ancestors; of c
must be understood that this was last, in the sense
sexual apparatus acquired the independent form of a
organ-system subsequently to all the other organ
simplest form, that of reproductive cells, is certain
ancient. Not only the lowest Worms and Plant
propagate sexually, but this was also probably the
the common parent-form of all Metazoa, in the G
but in all these low animals, the reproductive cells

nstitute special sexual organs in a morphological sense; ey are rather, as we shall soon see, simple component parts other organs.

Like the organ-systems of the human body, the tissues, hich compose these systems, are of different ages and of rying morphological value. As we were justified in awing an inference as to the phylogenetic sequence in e of the organ-systems, from the ontogenetic sequence which they successively appear in the embryo, so are e justified in inferring the order in which the tissues iginated during the course of tribal history, from the quence of the stages in germ-history. The result of this a phylogenetic classification (Table XXXVIII.) of the ssues of the human body, similar to that of the organs Table XXXIX., p. 367).

The tissues of the human body, arising by division of labour, the separation and the connection of the component cells, may be distributed, with reference to their development, in the four following distinct groups:—1, covering-tissue (*epithelium*); 2, connective tissue (*connectivum*); 3, nerve and muscular tissue (*neuro-musculum*); and 4, vascular tissue (*vasalium*). Of these, in accordance with the Gastræa theory, we must regard the covering-tissue as the oldest and most original form, as the actual primary or primitive tissue; the three other main forms must, on the other hand, be considered as secondary or derived forms, which developed at a later period from the covering-tissue; the connecting-tissue first, then the neuro-muscular, and lastly the vascular tissue.

The oldest and most original form of tissue is, undoubtedly, the covering-tissue (*epithelium*), the cells of

which are arranged in a simple strata-like way, and e over the outer and inner surface of the body as a prot and secreting cover. This is proved by the simple fac the formation of the tissues of the animal body b with the formation of the gastrula, and that the itself consists solely of two simple epithelial strata, skin-layer (Fig. 274, *e*), and of the intestinal-laye Histologically, the two primary germ-layers are s epithelia. When these, afterwards, separate into the secondary germ-layers, the skin-sensory layer become outermost of the external coverings (dermal-epithel the intestinal-glandular layer becomes the innermost internal coverings (gastral-epithelium). The tissue c outer skin and of all its appendages, such as nails (Fig

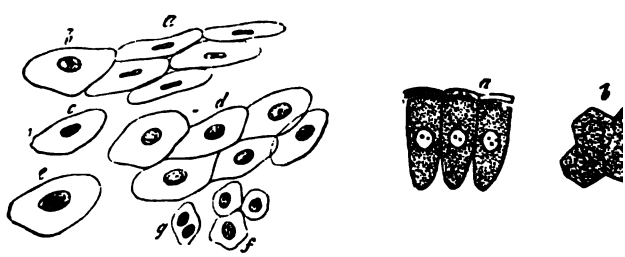


FIG. 289.—Tissue of the nails (flattened epithelium): *a–e*, cells upper strata; *f*, *g*, cells of the lower strata.

FIG. 290.—Tissue of the covering of the small intestine (co epithelium): *a*, side view of three cells (with thicker, porous bord surface view of four cells. (After Frey.)

hairs, skin-glands, etc., arise from the skin-sensory (Cf. Table XXIX., p. 232.) The inner covering of the tinal tube and of its intestinal glands originates, o other hand, from the intestinal-glandular layer (Fig. 2

Connective tissue (*connectivum*) must be regarded as ming, in order of phylogenetic age, the second main oup of tissues. This is morphologically characterized by e intercellular substance, which develops between the

FIG. 291.—Jelly-like tissue from the vitreous body of an embryo of four onths (round cells as jelly-like intercellular substance).

FIG. 292.—Cartilage-tissue of the fibrous or netted cartilage of the ear. ell: *a*, cells; *b*, intercellular mass; *c*, fibres in the latter. (After Frey.)

ells, physiologically, by the double part which it plays, s connecting substance and as complementary substance etween the other tissues, as an inner supporting substance nd as a protective covering for the inner organs. Of the umerous forms and varieties of connective tissue, we regard e jelly-like tissue (Fig. 291; Fig. 6, vol. i. p. 126), the fatty issue, and the chorda tissue as the earlier; the fibrous, artilaginous (Fig. 292), and bone-tissue (Fig. 5, vol. i. p. 126) s the more recent formations. All these various forms of onnective tissue are products of the middle germ-layer, r mesoderm; or, more accurately, of the two fibrous layers, f which the skin-fibrous layer is originally derived from he exoderm, the intestinal-fibrous layer from the entoderm.

The nerve-muscular tissue (*neuro-musculum*) is of much nore recent origin than the connective tissue. If epithelial issue represents a primary period in tribal history, and

connective tissue a secondary period, then we may
racterize a third, much later period, by nerve-muscle ti

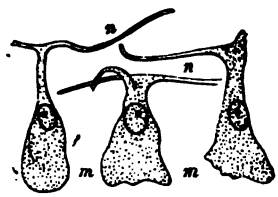


FIG. 293.

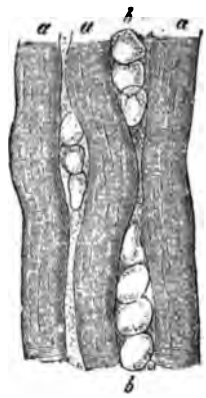


FIG. 295.

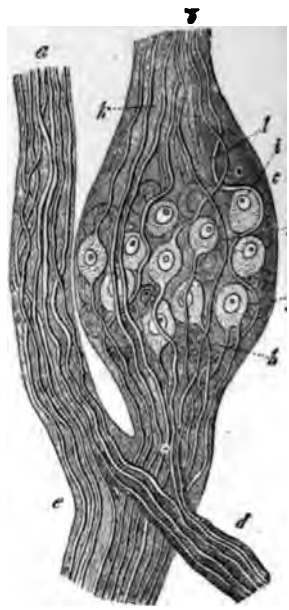


FIG. 294.

FIG. 293.—Nerve-muscle tissue. Three cells from Hydra: n
nervous; *m*, inner, muscular part of the cells. (After Kleinenberg.

FIG. 294.—Nerve-tissue (from a spinal nerve knot): *a*, ant
posterior root of the spinal nerve; *d*, *e*, fibrous nerve-stem; *f*, *g*, *h*,
cells in ganglion (*f*, unipolar, *g*, *h*, bipolar cells); *k*, *l*, nerve fibres.
Frey.)

FIG. 295.—Muscle-tissue. Three pieces of striped muscle fibre (
terfibrous fat-cells (*b*). (After Frey.)

For while in the lowest Plant Animals the body c
merely of covering tissue, and while in many

hytes a middle layer of connective tissue develops een the two primary germ-layers, it is only in the highly developed Plant Animals that muscle and nerve e is formed. As has already been said, the latter first ared as a common nerve and muscle tissue (*neuro-culum*, Fig. 293; cf. p. 358). It was only afterwards the muscle-tissue (Fig. 295) separated from the nerve-e (Fig. 294). The greater part of the nerve-tissue is ved from the skin-sensory layer, the greater part of the cle-tissue from the skin-fibrous layer.

Vascular tissue (*vasalium*) must be regarded as forming

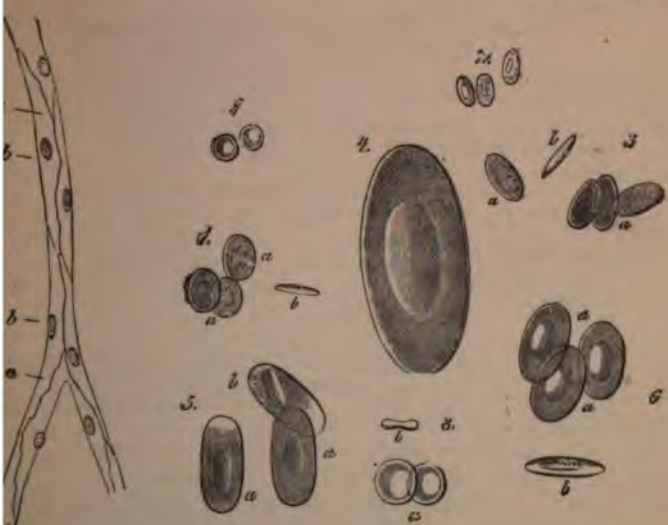


FIG. 296.—Vascular tissue (*vasalium*). A hair-vessel from the entery: *a*, vascular cells; *b*, the kernels of these ("endothelium").
FIG. 297.—Red blood cells (corpuscles) of various Vertebrates (equally nified): 1, Human; 2, Camel; 3, Pigeon; 4, Proteus (p. 129); 5, Water-mander (*Triton*); 6, Frog; 7, Fish (*Cobitis*); 8, Lamprey (*Petromyzon*). rface view; *b*, edge view. (After Wagner.)

TABLE XXXVIII.

Systematic Survey of the Sequence, according to Age, of the Human Tissue-groups.

(Phylogenetic Classification of Vertebrate Tissues.)

FIRST GROUP: PRIMARY TISSUES (*Epithelium*).

1. First Histological Stage of Evolution.

I. Covering-tissue (*Epithelium*).

I. *A.* Skin-covering tissue (*Epithelium dermale*). Skin-layer, or Exoderm, of Gastrula (afterwards skin-sensory layer)		1. Outer skin (*Epidermis*) 2. Glands of outer skin 3. (Earliest site of origin of the sperm-cells?)
I. *B.* Intestinal covering tissue (*Epithel. gastrale*). Intestinal layer, or Entoderm, of Gastrula (afterwards the intestinal-glandular layer)		1. Real intestinal epithelium 2. Epithelium of the intestinal glands 3. (Earliest site of origin of egg-cells)

SECOND GROUP: SECONDARY TISSUES.

(All derived from the Covering-tissue, or Epithelium.)

2. Second Histological Stage of Evolution.

II. Connective-tissue (*Connectivum*).

II. *C.* Filling-up tissue (*Tela conjunctiva*) (softer [surrounding] connective tissue)		1. Jelly-like tissue 2. Fatty tissue 3. Fibrous tissue
II. *D.* Supporting tissue (*Tela skeletaris*) (firmer [supporting] connective tissue)		4. Chorda tissue 5. Cartilaginous tissue 6. Bone-tissue

3. Third Histological Stage of Evolution.

III. Nerve-muscle Tissue (*Neuro-musculum*).

III. *E.* Nerve-tissue (*Tela nervea*). Original outer portion of the nerve-muscle cells of the Exoderm	1. Nerve-cells (Ganglion-cells)	1. *a.* Peripheric nerve-cells (Red-cells of the sense-organs) 1. *b.* Central nerve-cells (mind-cells)
	2. Nerve-fibres (Nerve-tubes)	2. *a.* Sheath-less nerve-fibres (pale, or medulla-less fibres) 2. *b.* Sheathed nerve-fibres (dark fibres with medulla)
III. *F.* Muscle-tissue (*Tela muscularis*). Original inner portion of the nerve-muscle cells of the Exoderm	1. One-celled muscle-fibres	1. *a.* Smooth contractile fibre-cells 1. *b.* Striped contractile fibre-cells
	2. Many-celled muscle-fibres	2. *a.* Smooth muscle-masses 2. *b.* Striped muscle-masses

4. Fourth Histological Stage of Evolution.

IV. Vascular Tissue (*Vasalium*).

IV. *G.* Vascular lining tissue (*Tela vasalis*). Inner wall-covering of the Cœlom system	1. Cœlarium (Cœlom-epithelium)	1. *a.* Exocœlarium (Parietal Cœlom-epithelium) (and secondary site of origin of the sperm-cells?) 1. *b.* Endocœlarium (Visceral cœlom-epithelium) (and secondary site of origin of the egg-cells?)
	2. Endothelium (Vascular epithelium)	2. *a.* Endothelium of the lymph-vessels 2. *b.* Endothelium of the blood-vessels
IV. *H.* Lymph-tissue (*Tela lymphatica*). Liquid contents of the Cœlom system		1. Lymph (Colourless blood-cells and fluid intercellular substance) 2. Blood (Red blood-cells and fluid intercellular substance)

TABLE XXXIX.

Systematic Survey of the Sequence, according to Age, of the Human Organ-systems.

(Phylogenetic Classification of Vertebrate Organs.)

(On the right are given the Ancestral Stages, in which the respective organs probably first appeared.)

1. First Stage in the Evolution of Organs.

I. Skin and Intestinal Systems.

The two Systems appear first, and simultaneously, in the Gastread ancestors.

A. Skin-system (*Systema dermale*)	*A* 1. Simple exoderm	Gastræads
	A 2. Outer skin (Skin-sensory layer) and leather skin (Skin-fibrous layer)	Worms
	A 3. Outer skin, with hairs, glands, etc.	Mammals
B. Intestinal system (*Systema gastrale*)	*B* 1. Simple entoderm	Gastræads
	B 2. Intestinal epithelium (Intestinal-glandular layer) and intestinal muscular skin (Intestinal-fibrous layer)	Worms
	B 3. Gill-intestine and stomach-intestine	Chorda-animals

2. Second Stage in the Evolution of Organs.

II. Nerve and Muscle Systems.

The two Systems appear first, and simultaneously, in the Primitive Worm ancestors.

C. Nerve-system (*Systema nerveum*)	*C* 1. Upper throat ganglia	Primitive Worms
	C 2. Simple medullary tube	Chorda-animals
	C 3. Brain and spinal marrow	Monorhina
D. Muscle-system (*Systema muscalare*)	*D* 1. Skin-muscle pouch	Primitive Worms
	D 2. Side muscles of the trunk	Acrania
	D 3. Trunk and limb muscles	Fishes

3. Third Stage in the Evolution of Organs.

III. Kidney and Vascular Systems.

The two Systems first appear, one after the other, in the Soft-worm ancestors (*Scolecida*).

II. *E.* Kidney-system (*Systema renale*)	*E* 1. Primitive kidney canals	Scolecida
	E 2. Segmental canals	Acrania?
	E 3. Primitive kidneys	Monorhina
	E 4. Permanent kidneys	Protamnia
II. *F.* Vascular system (*Systema vasculare*)	*F* 1. Simple cœlom	Scolecida
	F 2. Dorsal and ventral vessels	Worms
	F 3. Heart (part of the ventral vessel)	Chorda-animals
	F 4. Heart, with auricle and ventricle	Monorhina

4. Fourth Stage in the Evolution of Organs.

IV. Skeleton and Sexual Systems.

The two Systems first appear, one after the other, in the Chordonia-ancestors.

IV. *G.* Skeleton-system (*Systema skeletare*)	*G* 1. Simple notochord	Chorda-animals
	G 2. Cartilaginous primitive skull	Monorhina
	G 3. Gill-arches, ribs, limbs	Selachii
	G 4. Limbs, with five digits	Amphibia
IV. *H.* Sexual system (*Systema sexuale*)	*H* 1. Simple hermaphrodite glands	Chorda-animals
	H 2. Distinct testes and ovaries	Acrania
	H 3. Seed-duct and oviduct	Selachii
	H 4. Phallus (penis, clitoris)	Protamnia

the most recent group of tissues, that which originated l
Under this name are included those epithelial-like t
which line the closed inner cavities of the body (the co
chest-cavity, ventral cavity, heart-cavity, blood-vessel,
(Fig. 296). In addition to this vascular carpet (co
thelium), the liquids containing cells, which fill th
cavities (lymph, blood, serum, etc.), must be classed wi
this tissue (Fig. 297). All these tissues may be grouped
vasalia. His wrongly ascribed to them a quite differe
"parablastic" origin (from the nutritive yelk); they a
however, products of the intestinal-fibrous layer (and partly
perhaps, of the skin-fibrous layer). As the cœloma and th
whole vascular system is of more recent phylogenetic orig
its peculiar tissues must also be more recent.

This phylogenetic explanation of the ontogenetic su
cession of the tissues and of the organ systems arising fro
them, appears to me to be satisfactorily proved by Co
parative Anatomy, and by the Gastræa theory. If it
correct, it discloses an interesting glimpse into the entir
various age of the most important constituent parts of
body. The human skin and intestine are, according to t
many thousands of years older than the muscles and ner
these again are much more ancient than kidneys and blo
vessels, and the latter, finally, are many thousands of ye
older than the skeleton and the sexual organs. The c
mon view, that the vascular system is one of the m
important and original organ-systems, is, therefore, e
neous; it is as false as the assumption of Aristotle
the heart is the first part to form in the incubated ch
On the contrary, all lower Intestinal Animals show plai
that the historic evolution of the vascular system did

till a comparatively late period. Not only all Plant als (Sponges, Corals, Hydropolyps, Medusæ), but also ower Worms (*Acœlomi*), are entirely destitute of lar system. In both groups, the fluid acquired by ion is conveyed directly from the intestinal tube, gh processes of this latter (the gastro-canals), into the ent parts of the body. It is only in the intermediate igher Worms that the vascular system first begins to op, in consequence of the formation of a simple cavity *ma*), or of a system of connected spaces, round the inal tube, in which cavities the nutritive fluid (blood) ed through the intestinal wall, collects.

n the human ancestral line we meet with this first nent of the vascular system in that group of Worms h we spoke of as Soft Worms (*Scolecida*; p. 85). Soft Worms, as we said, formed a series of intermediate s between the lowest bloodless Primitive Worms *helminthes*) and the Chorda-worms (*Chordonia*), which already provided with a vascular system and a noto-d. The vascular system must have begun, in the older ecida, with a very simple cœlom, a "body-cavity," with blood, and which surrounded the intestinal tube. origin was probably due to the accumulation of itive fluid in a cleft between the intestinal-fibrous and the skin-fibrous layer. A vascular system in simplest form is yet found in the Moss-polyps (*Bryozoa*) he Wheel-animalcule (*Rotatoria*), and in other lower ms. The inner, visceral, part of the wall of the cœlom aturally, formed by the intestinal-fibrous layer (*endo-r*), the outer, parietal, part by the skin-fibrous layer *ælar*). The cœlom fluid, collected between the two,

may contain detached cells (lymph-cells) from either f layer.

A first advance in the development of this most tive vascular system was accomplished by the format canals or blood-conducting tubes, which developed, pendently of the cœloma, in the intestinal wall, that the intestinal-fibrous layer of the wall. These real vessels, in the stricter sense, appear in very di form in Worms of the intermediate and higher g sometimes they are very simple, sometimes very co Two primordial "primitive vessels" must be regar representing that form, which probably formed the f the more complex vascular system of Vertebrates; th a dorsal vessel, which passes from front to back alo middle line of the dorsal wall of the intestine, and a v vessel which passes, in the same direction, along the r line of the ventral wall. Both at the front and back these two vessels are linked together by a loo rounding the intestines. The blood enclosed in th tubes is driven forward by the peristaltic contract this.

The further development of this simplest rudim blood-vessel system is evident in the class of the l Worms (*Annelida*), in which we find it in very v stages of development. In the first place, many verse connections probably arose between the dors ventral vessels, so as to encircle the intestine (Fig Other vessels then penetrated into the body-wa branched, so as to conduct blood to this part. As in ancestral Worms, which we have called Chordon front section of the intestine changed into a gill-body

ılar loops, within the wall of this gill-body, which
d from the ventral vessel to the dorsal vessel, became
fied into respiratory gill-vessels. Even at the present
the organization of the remarkable Acorn-worm
ınoglossus) exhibits a similar condition of gill-circula-
(Fig. 186, p. 86).

. further important advance is exhibited,
ıg extant Worms, in the Ascidia, which
be regarded as the nearest blood-rela-
to our primitive Chordonia ancestors.
hese we find, for the first time, a real
, that is, a *central organ of the circula-*
of the blood, by the pulsating contractions
e muscular wall of which the blood is
n forward in the vascular tubes. The
appears here in the simplest form, as
ndle-shaped pouch which passes at both
into a main vessel (Fig. 188, c. p. 90;
XI. Fig. 14, *hz*). The original position

. 298.—Blood-vessel system of a Ringed Worm
ris); front section: *d*, dorsal vessel; *v*, ventral
; *c*, transverse connection between the two (en-
like a heart). The arrows indicate the direction of
ood current. (After Gegenbaur.)

e heart on the ventral side, behind the gill-body of the
lian, plainly shows that it originated in a local dilation
section of the ventral vessel. The alternating direc-
of the movements of the blood, which has already been
ioned, is remarkable; the heart expels the blood alter-
y through the anterior and through the posterior end.
is very suggestive, because in most Worms the blood

in the dorsal vessel moves from back to front, v
Vertebrates, on the contrary, it flows in the opposit
tion, from front to back. As the heart of the A
constantly alternates between these two opposite di
it exhibits permanently, to a certain extent, the phyl
transition between the older direction of the dorsa
current toward the front in Worms, and the newe
tion of the same toward the rear in Vertebrates.

As in the more recent Chorda Animals, whic
rise to the Vertebrate tribe, the newer direction
permanent, the two vessels which proceeded fr
two ends of the heart-pouch, acquired a constant
cance. The front section of the ventral vessel, sinc
has steadily conducted the blood from the heart,
consequently, as an artery; the hinder section
ventral vessel, on the contrary, leads the blood, circ
in the body, back into the heart, and must, there
called a vein. In reference to their relation to t
sections of the intestine, we may speak of the latter
accurately, as the intestinal vein, and of the former
gill-artery. The blood contained in both vessels,
alone fills the heart also, is venous blood; that is, con
much carbonic acid. On the other hand, the blood
flows from the gills into the dorsal vessel is th
furnished with oxygen; is arterial blood. The most d
branches of the arteries and veins pass into each
within the tissue, through a network of extremel
neutral hair-vessels or capillaries (Fig. 296).

If we now turn from the Ascidia to the nearest
form, the Amphioxus, we are immediately surprised
apparent retrogression in the development of the va

ystem. The Amphioxus, as has been stated, has no real eart; but the blood is circulated in its vascular system by ie main vascular stems themselves, which contract and ulsate along their whole length. (Cf. Fig. 151, vol. i. p. 420.) dorsal vessel (aorta), situated over the intestine, absorbs ie arterial blood from the gills and propels it through the ody. The venous blood, in its return, collects in a ventral essel (intestinal vein), situated under the intestine, and ius returns to the gills. Numerous vascular gill-arches, hich accomplish respiration, and absorb oxygen from the ater and emit carbonic acid, unite the ventral vessel ith the dorsal vessel before. As, in Ascidia, that section f the ventral vessel which also forms the heart in Skulled nimals (*Craniota*), is already fully developed into a simple eart-pouch, we must regard the absence of the latter in the mphioxus as the result of retrogression, as a reversion, in iese Acrania, to the older form of vascular system, as it xists in Scolecida and many other Worms. We may ssume that those Acrania which actually formed part of ur ancestral line did not share this relapse, but rather nherited the one-chambered heart from the Chordonia and ransmitted it directly to the older Skulled Animals *Craniota*).

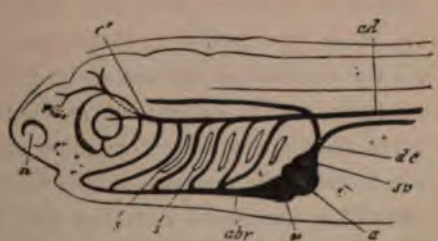
The Comparative Anatomy of Skulled Animals clearly xhibits the further phylogenetic development of the blood-essel system. In the lowest stage of this group, in the Cyclostoma (p. 102), we first meet with a real lymph-vessel ystem, side by side with the blood-vessel system, a system f canals which collect the colourless fluid flowing from the issues, and conduct it to the blood-current. Those lymph-essels which absorb the milky, nutritive fluid, obtained

directly by digestion, from the intestinal wall, and con[illegible] it to the blood-current, are distinguishable as chyle-ves[illegible] or "milky juice vessels." While the chyle, or milky ju[illegible] in consequence of the great amount of fat globules wh[illegible] it contains, appears milk white, the real lymph is colo[illegible] less. The chyle, as well as the lymph, contain the sa[illegible] colourless amœboid cells (Fig. 9, vol. i. p. 132), which are al[illegible] distributed in the blood as colourless blood-cells (corpuscle[illegible]); the latter contains, in addition, the much greater quantity of red blood-cells (corpuscles), which gives the blood of Skulled Animals its red colour. The distinction, common to all Craniota, between lymph-vessels, chyle-vessels, and blood-vessels, is to be regarded as the result of a division of labour which took place between different portions of an original unitary, primitive blood-vessel system (or hæmo-lymph system).

The heart, the central organ of the circulation of the blood, which exists in all Craniota, also exhibits an advance in structure, even in the Cyclostoma. The simple spindle-shaped heart-pouch is separated into two divisions, or chambers, which are divided by two valves (Plate XI. Fig. 16, *hv*, *hk*). The posterior division, the fore chamber (*atrium*, *hv*), absorbs the venous blood from the veins of the body, and discharges it into the anterior division, the chamber, or main chamber (*ventriculus*, *hk*). From here it is propelled by the gill-artery stem (the foremost section of the ventral vessel) into the gills.

In Primitive Fishes (*Selachii*), an arterial stalk (*bulbus arteriosus*), separated by valves, originates, as a distinct section, from the foremost end of the ventricle. It forms the enlarged, hindmost end of the gill-artery stem (Fig.

abr). From each side of this, from five to seven gill-ries proceed; these rise between the gill-openings (*s*) he gill-arches, encircle the throat, and combine above a common aorta-stem, the continuation of which, ing backward above the intestine, corresponds to the al vessel of Worms. As the arched arteries distribute nselves in a respiratory capillary net over the gill-es, they thus contain venous blood in their lower part arterial gill-arches), and arterial blood in their upper (as aorta-arches). The points at which separate aorta-es unite, which occur on the right and left sides, are ed aorta-roots. Of an originally greater number of a-arches, only five pairs are retained, and from these (Fig. 300), in all higher Vertebrates, the most im-ant parts of the arterial system develop.



'ig. 299.—Head of an embryonic Fish, with the rudiment and the l-vessel system; seen from the left side: *dc*, Cuverian duct (point of n of the front and hind main veins); *sv*, venous sinus (enlarged inal portion of the Cuverian duct); *a*, auricle; *v*, main chamber; gill-artery stem; *s*, gill-openings (between the arterial arches); *ad*, ; *c''*, head-artery (carotis); *n*, nose-groove. (After Gegenbaur.)

The appearance of the lungs, connected with the respi-on of air, which first occurs in the Dipneusta, is most ortant in the further developement of the arterial

system. In Dipneusta, the auricle of the heart se
into two halves by the formation of an incomplete pa
Only the right auricle now absorbs the venous blood
body-veins. The left auricle, on the other hand, a
the arterial blood of the lung-veins; both auricl
charge in common into the simple ventricle, in whi
two kinds of blood mingle, and are then propelled t
the arterial stalk into the arterial arches. From the
these latter spring the lung-arteries (Fig. 301, *p*);
convey a part of the mixed blood into the lungs, wh
remainder is driven through the aorta into the body.

From the Dipneusta upward, we trace a prog
development of the vascular system, which finally
with the loss of gill respiration, to a complete separa
the two parts of the double circulatory system. I
phibia, the partition between the two auricles b
complete. In their young form, these yet retai
respiration and the circulatory system as in Fishes, a
heart contains only venous blood; at a later peric
lungs, with their vessels, are developed also, and th
chamber of the heart then contains mixed blood. I
tamnia and Reptiles, the main chamber and the a
stalk belonging to it begin to separate, by the forma
a longitudinal partition, into two halves, and this pa
becomes complete in the higher reptiles on the one s
the parent-form of Mammals on the other. The rig
of the heart alone now contains venous blood, the le
only arterial, as in all Birds and Mammals. The
auricle receives venous blood from the body-veins, a
right ventricle propels this through the lung-arteri
the lungs; from there it returns as arterial blood t

the lung-veins to the left auricle, and is driven through the left ventricle into the body-arteries. Between the lung-arteries and lung-veins is situated the capillary system of the lesser, or lung-circulation; between the body-arteries and the body-veins lies the capillary system of the greater, or body-circulation. Only in the two highest Vertebrate

FIG. 300.—The five arterial arches of Skulled Animals (1–5) in their original form: *a*, arterial stalk; *a''*, main stem of the aorta; *c*, head-artery (carotis, anterior continuation of the aorta-roots). (After Rathke.)

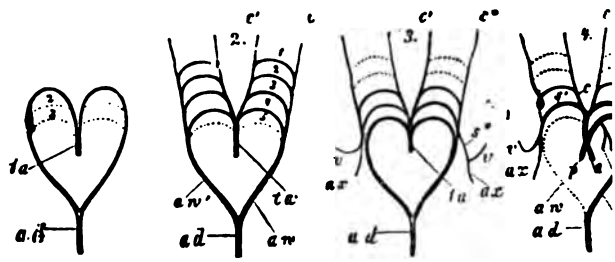
FIG. 301.—The five arterial arches of Birds; the light portions of the rudiment disappear; only the dark parts are permanent. Letters as in Fig. 300: *s*, arteries of the clavicula (sub-clavian); *p*, lung-artery; *p'*, branches of the same. (After Rathke.)

FIG. 302.—The five arterial arches of Mammals. Letters as in Fig. 301: *v*, vertebral artery; *b*, Botalli's duct (open in the embryo, afterwards closed). (After Rathke.)

classes, in Birds and Mammals, is this complete separation of the two courses of the circulation perfect. Moreover, this separation has taken place in the two classes independently of each other, as is shown by the unequal development of the aortas. In Birds, which are descended from Reptiles,

the right half of the fourth arterial arch has becoı permanent arterial arch (*arcus aortæ*, Fig. 301). (other hand, the latter has developed from the left l the same arch (Fig. 302) in Mammals, which are d descended from the Protamnia.

On comparing the arterial system in the various of the Skulled Animals (*Craniota*) in its matured con it appears in very various forms, and yet it devel all, from the same primitive form. This developmen place in man exactly as in other Mammals; especially modification of the five arterial arches precisely the s both cases (Figs. 303–306). At first, only a single



FIGS. 303–306.—Metamorphosis of the five arterial arches in th embryo (diagram after Rathke): *ta*, arterial stalk; 1, 2, 3, 4, 5, th arches from the first to the fifth pair; *ad*, main stem of the ao roots of the aorta. In Fig. 303, three of the arterial arches are given 304, the whole five (those indicated by dots are not yet developed); in the first two have again disappeared; in Fig. 306, the permanent stems are represented. The dotted parts disappear. *s*, Sub-clavia *v*, vertebral artery; *ax*, axillary artery; *c*, carotid artery (*c'*, inner carotis); *p*, pulmonary artery (lung-artery).

arches develop, and these lie on the inner surface first pair of gill-arches (Figs. 147–150, vol. i. pp. 39 Fig. 303). A second and a third pair of arches then

ind the first, and these are situated on the inner surface he second and third gill-arches. At length, a fourth and fth pair appear behind the third (Fig. 304); but while latter are developing, the first two are again disappear- by growing together (Fig. 305). The permanent main ries develop only from the three posterior arterial hes (3, 4, 5, in Fig. 304), the lung-arteries from the last Fig. 306). (Cf. with this Fig. 302.)

The human heart also (Fig. 314) develops exactly like that other Mammals. We have already considered the first prin- les of its germ-history (vol. i. pp. 392–395, Figs. 143–147), ich essentially corresponds with its Phylogeny.[191] We saw t the very first rudiment of the heart is a spindle-shaped ckening of the intestinal-fibrous layer in the ventral wall the head-intestine (Fig. 143, *df*). This spindle-shaped nation then becomes hollow, forms a simple pouch, and arates from the place at which it originated, so that it n lies freely in the cardiac cavity (Figs. 145, 146). This ich bends into the form of an S (Fig. 144, *c*), and, at the ne time, turns spirally on an imaginary axis, so that the sterior part lies on the dorsal surface of the anterior rt. The combined yelk-veins open into its posterior tremity; from the anterior extremity proceed the arterial hes (Fig. 150, vol. i. p. 398).

This first rudiment of the human heart, which encloses very simple cavity, corresponds to the heart of the As- lians, and must be regarded as a reproduction of the heart the Chordonia; it now, however, separates into two, and en three parts, thus exhibiting for a very brief period the art-structure of the Cyclostoma and of Fishes. The spiral rn and curve of the heart increases, and, simultaneously,

two shallow transverse indentations of the circu
appear, which externally mark the three sections (
308). The anterior section, which is turned tow

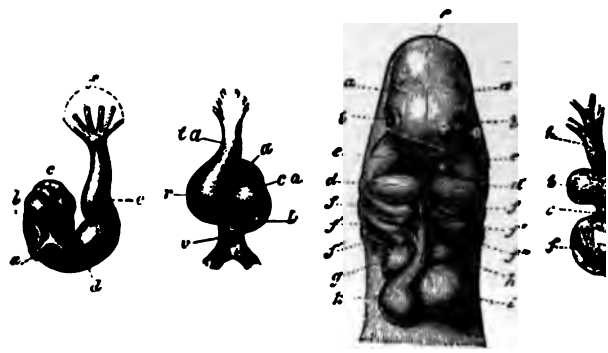


FIG. 307.—Heart of an embryonic Rabbit, from behind: *a*, ;
b, auriculæ; *c*, auricle (*atrium*); *d*, ventricle; *e*, artery-stalk; *f*,
three pairs of arterial arches. (After Bischoff.)

FIG. 308.—Heart of the same embryo (Fig. 307), from th
yelk-veins; *a*, auricle; *ca*, auricular canal; *l*, left ventricle
ventricle; *ta*, artery-stalk. (After Bischoff.)

FIG. 309.—Heart and head of an embryonic Dog, from
a, fore-brain; *b*, eyes; *c*, mid-brain; *d*, primitive lower jaw;
upper jaw; *f*, gill-arches; *g*, right auricle; *h*, left auricle; *i*, lef
k, right ventricle. (After Bischoff.)

FIG. 310.—Heart of the same embryo, from behind: *a*, entr
yelk-veins; *b*, left auricular process; *c*, right auricular process;
e, auricular canal; *f*, left ventricle; *g*, right ventricle; *h*, a
(After Bischoff.)

ventral side, and from which the aortal arches
reproduces the arterial stalk (*bulbus arteriosus*
Selachii. The central section is the rudiment of
chamber, or ventricle (*ventriculus*); and the
section, the one turned toward the dorsal side, int
the yelk-veins open, is the rudiment of a simpl

rium). The latter, like the simple auricle of the heart the Fish, forms a pair of lateral protuberances, the heart s, or auricular appendages (*auriculæ*, Fig. 307, *b*); and nce the indentation between the auricle and ventricle is led the auricular canal (*canalis auricularis*, Fig. 308, *ca*). e heart of the human embryo is now a complete Fish art.

Corresponding exactly with the Phylogeny of the human art (Table XLI.), its Ontogeny exhibits a gradual tran-tion from the Fish heart through the Amphibian heart to e Mammalian heart. The most important step in this vance is the formation of a longitudinal partition, im-erfect at first, afterwards complete, by which all the three ections of the heart are separated into a right (venous) and left (arterial) half. (Cf. Figs. 309–314.) The auricle (*atrium*) is thus divided into a right and a left auricle, each of which acquires its respective auricular process; the body-veins discharge into the right auricle (ascending and descending *vena cavæ*, Fig. 311, *c*, Fig. 313, *c*); the left auricle receives the lung-veins. Similarly, a superficial "interventricular furrow" (*sulcus interventricularis*, Fig. 312, *s*) appears at an early period on the main chamber of the heart, the external expression of the internal partition, by the formation of which the ventricle is divided into two chambers, a right (venous) and a left (arterial) ventricle. Finally, a longitudinal partition forms, in a similar way, in the third section of the primitive heart, which so much resembles that of a Fish, in the arterial stalk, which is also externally indicated by a longitudinal furrow (Fig. 312, *af*). This separates the cavity of the artery-stalk into two lateral halves; the main lung artery, which opens into the

FIG. 311.

FIG. 312.

FIG. 313.

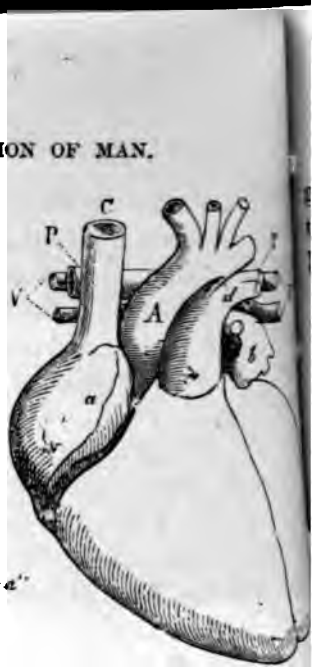


FIG. 314.

FIG. 311.—Heart of a human embryo of four weeks; 1, from the fr
2, from the back; 3, open, and with the upper half of the auricle remo
a', left auricular process; *a''*, right auricular process; *v'*, left ventr
v'', right ventricle; *ao*, artery-stalk; *c*, upper hollow vein (*vena cava*
right, *cs*, left); *s*, rudiment of the partition, between the chambers. (
Koelliker.)

FIG. 312.—Heart of a human embryo of six weeks, from the f
r, right ventricle; *t*, left ventricle; *s*, furrow between the two ventr
ta, artery-stalk; *af*, furrow on its surface; at the right and left ar
two large auricular processes of the heart. (After Ecker.)

FIG. 313.—Heart of a human embryo of eight weeks, from be
a', left auricular process; *a''*, right auricular process; *v'*, left vent
v'', right ventricle; *cd'*, right upper *vena cava*; *cs*, left upper *vena*
ci, lower *vena cava*. (After Koelliker.)

FIG. 314.—Heart of human adult, perfectly developed, from the fro
its natural position: *a*, right auricular process (below it, the right ventr
b, left auricular process (below it, the left ventricle); *C*, upper *vena*
V, lung-veins; *P*, lung-artery; *d*, Botalli's duct; *A*, aorta. (After Me

right ventricle, and the aorta-trunk, which opens into
left ventricle. Not until all these partitions are comp
is the lesser, or lung-circulation, entirely distinct from

ater, or body-circulation; the right half of the heart is centre of motion for the former, the left half for the ter. (Cf. Table XLI.)

In the human embryo, and in all other Amniota, the art originally lies far forward on the lower side of the d, as in Fishes it remains permanently near the throat. terwards, with the advancing development of the neck l chest, the heart continually moves further back, until last it is situated in the lower part of the breast between e lungs. At first its position is symmetrical, in the central ane of the body, so that its longitudinal axis corre- onds with that of the body (Plate IV, Fig. 8). In most ammals it retains this symmetrical position permanently; ut in the Apes the axis begins to incline obliquely, and to ove the apex of the heart to the left side. This inclination carried furthest in the Man-like Apes; in the Chim- anzee, Gorilla, and Orang, which also resemble Man in his oblique position of the heart.

The germ-history of all other parts of the vascular system, ike that of the heart, point out many and valuable facts re- arding the history of our descent. But as an accurate know- edge of the complex arrangement of the entire vascular system f Man and other Vertebrates is required, in order to follow the natter sufficiently far to make it intelligible, we cannot here nter into any further detail.[192] Moreover, many important eatures in the Ontogeny of the vascular system, especially n regard to the derivation of its various parts from the econdary germ-layers, are as yet very obscure and doubtful. This is true, for example, of the question as to the origin of he cœlom-epithelium—that is, of the cell-layer coating the body-cavity. Probably there is an important phylogenetic

distinction between the exocœlar, or the parietal co epithelium, which originates from the skin-fibrous laye the endocœlar, or the visceral cœlom-epithelium, w is derived from the intestinal-fibrous layer. The fo is, perhaps, connected with the male germ-epithelium rudiment of the testes), the latter with the female ge epithelium (the rudiment of the ovary). (Cf. Chapter XX

TABLE XL.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGE OF THE HUMAN VASCULAR SYSTEM.

I. *First Period: Vascular System of the earlier Scolecida.*

Between the skin-covering and the intestinal wall is formed a sim body-cavity (*cœloma*), or a perienteric cavity (as in the extant *Bryozoa* other *Cœlomati*).

II. *Second Period: Vascular System of the more recent Scolecida.*

The first real blood-vessels form in the intestinal wall (in the intesti fibrous layer), a dorsal vessel in the central line of the dorsal side of intestinal tube, and a ventral vessel in the central line of its ventral s The two vessels are connected by several circular vessels, encircling intestine.

III. *Third Period: Vascular System of the earlier Chordonia.*

By the modification of the anterior half of the intestine into a intestine, the anterior section of the ventral vessel becomes a gill-art and the anterior section of the dorsal vessel a gill-vein; between the a gill capillary network develops.

IV. *Fourth Period: Vascular System of the more recent Chordonia.*

The portion of the ventral vessel, lying immediately behind the intestine, enlarges to a simple heart-pouch (Ascidian).

V. *Fifth Period: Vascular System of the Acrania.*

The ventral vessel (intestinal vein) forms, round the developing liver, the first rudiment of a vena portæ system.

VI. *Sixth Period: Vascular System of the Cyclostomi.*

The single-chambered heart divides into two chambers; a posterior ventricle, and an anterior auricle. The lymph-vessel system develops side by side with the blood-vessel system.

VII. *Seventh Period: Vascular System of the Primitive Fishes, or Selachii.*

From the anterior section of the main chamber of the heart arises an aortic-stalk or trunk, from which five (?) pairs of arterial arches proceed.

VIII. *Eighth Period: Vascular System of the Mud-fishes.*

From the last (fifth) pair of arterial arches the lung-arteries develop, in the Dipneusta.

IX. *Ninth Period: Vascular System of Amphibia.*

The gill-arches gradually disappear with the gills. The right and left aortal arches remain.

X. *Tenth Period: Vascular System of Mammals.*

The separation of the greater from the lesser circulation is complete. The right aortal arch unites with Botalli's duct.

TABLE XLI.

SYSTEMATIC SURVEY OF THE MOST IMPORTANT PERIODS IN THE PHYLOGENY OF THE HUMAN HEART.

I. *First Period: Heart of Chordonia.*

The heart forms a simple spindle-shaped enlargement of the ventral vessel, with an alternating blood-current (as in Ascidia).

II. *Second Period: Heart of Acrania.*

The heart is like that of *Chordonia*, but the blood-current acquires a constant direction, passing only from back to front. (Retrograded in Amphioxus.)

III. *Third Period: Heart of Cyclostoma.*

The heart divides into two chambers, a posterior auricle (*atrium*) an anterior ventricle (*ventriculus*).

IV. *Fourth Period: Heart of Primitive Fishes.*

From the anterior section of the ventricle is differentiated an ar stalk (*bulbus arteriosus*), as in all Selachii.

V. *Fifth Period: Heart of the Mud-fishes.*

The auricle divides, by an imperfect and interrupted partition a right and a left half, as in Dipneusta.

VI. *Sixth Period: Heart of Amphibia.*

The partition between the right and left auricles becomes complete the higher Amphibia.

VII. *Seventh Period: Heart of Protamnia.*

The main chamber of the heart divides, by an incomplete partitio a right and a left half, as in Reptiles.

VIII. *Eighth Period: Heart of Monotrema.*

The partition between the right and left ventricles becomes compl in all Mammals.

IX. *Ninth Period: Heart of Marsupials.*

The valves between the auricles and ventricles (atrio-ventricular together with the connecting filaments and papillary muscles belon them, are differentiated from the muscular masses of Monotremes.

X. *Tenth Period: Heart of Apes.*

The main axis of the heart, lying in the central line of th becomes oblique, so that the apex is turned to the left, as in Ap Man.

TABLE XLII.

atic Survey of those Primitive Organs which must probably be arded as homologous in Worms, Articulated Animals, Soft-bodied imals, and Vertebrates.[193]

'orms (rmes).	**Articulated Animals** (*Arthropoda*).	**Soft-bodied Animals** (*Mollusca*).	**Vertebrates** (*Vertebrata*).
I. *Products of the Differentiation of the Skin-sensory Layer.*			
skin (dermis) upper throat-(lia) ory organs er - vessels, ental organs)	1. Chitinous skin (*Hypodermis*) 2. Brain (upper throat-ganglia) 3. Shell-glands of the Crustacean (trachea of the Tracheata?)	1. Outer skin (*Epidermis*) 2. Brain (upper throat-ganglia) 3. Rudimentary kidneys (Primitive kidneys)	1. Outer skin (*Epidermis*) 2. Medullary tube (anterior part) 3. Primitive kidney-ducts (*Protureteres*) and segmental organs
II. *Products of the Differentiation of the Skin-fibrous Layer.*			
r-skin (ium) ether with the ular muscle-h?)	4. Leather-skin (Rudiment)	4. Leather-skin (*Corium*) (together with the muscles of the skin?)	4. Leather-skin (*Corium*) (together with the muscular layer of the skin?)
udinal cle-pouch	5. Trunk-muscles	5. Inner trunk-muscles	5. Side trunk-muscles
lar innermost layer of the -wall (also germ-plate?)	6. Exocœlar innermost cell-layer of the body-wall (also male germ-plate?)	6. Exocœlar parietal epithelium of the cœlom (also male germ-plate?)	6. Exocœlar parietal epithelium of the cœlom (also male germ-plate?)
I. *Products of the Differentiation of the Intestinal-fibrous Layer.*			
cavity (oma) cœlar outer- cell-layer he intestinal (together the female -plate?) l vessel	7. Body-cavity (*Cœloma*) 8. Endocœlar outermost cell-layer of the intestinal wall (together with the female germ-plate?) 9. Heart	7. Body-cavity (*Cœloma*) 8. Endocœlar visceral epithelium of the cœlom (together with the female germ-plate?) 9. Chamber of the heart (and main artery)	7. Pleuro-peritoneal cavity 8. Endocœlar visceral epithelium of the cœlom (together with the female germ-plate?) 9. Aorta (primordial)
al vessel	10. ——	10. ——	10. Heart (and gill-artery)
inal wall (except the epithe-)	11. Intestinal wall (except the epithelium)	11. Intestinal wall (except the epithelium)	11. Intestinal wall (except the epithelium)
Products of the Differentiation of the Intestinal-glandular Layer.			
inal epithe	12. Intestinal epithelium	12. Intestinal epithelium	12. Intestinal epithelium

CHAPTER XXV.

DEVELOPMENT OF THE URINARY AND SE

Importance of Reproduction.—Growth.—Simplest Form
duction: Division and the Formation of Buds (Gem
Forms of Sexual Reproduction: Amalgamation of
Cells; the Male Sperm-cell and the Female Egg-cel
Source of Love.—Original Hermaphroditism; Later
Sexes (Gonochorism).—Original Development of t
Sexual Cells from the Two Primary Germ-layers.—
and Female Entoderm.—Development of the Tes
Passage of the Sexual Cells into the Cœlom.—Herma
of the Embryonic Epithelium, or Sexual Plate.—Cl
Sexual Ducts.—Egg-duct and Seed-duct.—Developm
the Primitive Kidney Ducts.—Excretory Organs of
Canals" of Ringed Worms (*Annelida*).—Side Canals
—Primitive Kidneys of the *Myxinoides*.—Primitive
Animals (*Craniota*).—Development of the Pera
Kidneys in *Amniota*.—Development of the Urinary
Allantois.—Differentiation of the Primary and Se

the phenomena observed, and thus finds principles from which many experiences can be derived. This is more than mere experience; it is, so to speak, philosophical experience."—JOHANNES MÜLLER (1840).

If we judge of the importance of the organ-systems of the animal body according to the number and variety of phenomena which they present, and according to the physiological interest connected with them, we must recognize as one of the most important and interesting organic systems, the one to the development of which we now, finally, turn; the system of the reproductive organs. Just as nutrition is the first and most important condition of self-preservation of the organic individual, so by reproduction alone is the preservation of the kind or species effected, or, rather, the preservation of the long series of generations, which in their genealogical connection form the sum of the organic tribe, or phylum. No organic individual enjoys an eternal life. To each is granted but a short span of time for his individual evolution, a brief, fleeting moment in the long millions of years of the earth's organic history.

Reproduction in connection with Heredity has, therefore, long been regarded as, after nutrition, the most important fundamental function of the organism, and it is customary to make this a primary distinction between living bodies and lifeless or inorganic bodies. But this distinction is in reality not so deep and thorough as it at first appears, and as is generally assumed. For, if the nature of the phenomena of reproduction is closely considered, it is soon seen that it may be reduced to a more general quality, that of growth, which belongs to inorganic, as well as to organic bodies. Reproduction is a nutrition

and a growth of the organism beyond the individu which, therefore, raises a part of the organism to th of a whole (vol. i. p. 159). This is most clearly se observing the reproduction of the simplest and l organisms, especially of the Monera (p. 46) and of th celled Amœba (p. 48). In these, the simple individu sesses only the form-value of a single plastid. As so by continued nutrition and simple growth, this has re a certain size, it does not exceed that size, but fal simple division, into two similar halves. Each of two halves thenceforth leads an independent life, and grows, till, having reached the same limit of growth, i more divides. At each of these simple self-division new central points of attraction for the particles c body are formed, as foundations of the two new viduals.[194]

In many other Primitive Animals (*Protozoa*), the reproduction is accomplished, not by division, but l formation of buds (gemmation). In this case, the g which prepares the way for reproduction, is not total the case of division), but partial. Hence in the c gemmation, the product of local growth, which, as a forms a new individual, can be distinguished, as a individual, from the parent-organism from whi originates. The latter is older and larger than the f In the case of division, on the contrary, the two pr are of equal age and of equal form-value. F differentiated forms of asexual reproduction, con with gemmation, are, thirdly, the formation of germ- and, fourthly, the formation of germ-cells. The however, brings us directly to sexual reproduction, for

e opposed differentiation of the two sexes is the condition. my *Generelle Morphologie* (vol. ii. pp. 32–71), and in y "Natural History of Creation" (vol. i. p. 183), I ve fully discussed the connection of these various forms reproduction.

None of the earliest ancestors of Man and of the higher imals were capable of the higher function of sexual production, but multiplied only in an asexual manner, by ivision or gemmation, by the formation of germ-buds, or of erm-cells, as is still the case with most Primæval Animals r Protozoa. It was not until a later period in the organic istory of the earth, that sexual difference of the two exes could arise; and this took place at first in the simplest manner by the severance of two cells which amalgamated from the community of the many-celled organism. We may say that, in this case, growth, which is the condition necessary to reproduction, was attained by the union of two full-grown cells into a single cell which then exceeded its proper size ("copulation" or conjugation"). At first, the two united cells may have been entirely alike. Soon, however, by natural selection, a contrast must have arisen between them. For it must have been very advantageous to the newly-created individual in the struggle for existence, to have inherited various qualities from the two parent-cells. The complete development of this progressive contrast between the two producing cells, led to sexual differentiation. One cell became a female egg-cell, the other, a male seed or sperm cell.

The simplest form of sexual reproduction among existing animals, is exhibited in Gastræads and the lower Sponges, especially the Chalk Sponges, and, also, in the simplest

Hydroid Polyps. In the Haliphysema (Fig. 315) and the Olynthus the whole body is a simple intestinal pouch which is only essentially distinguished from the gastrula by the fact that it is adherent by the end opposite the mouth. The thin wall of the pouch consists only of the two primary germ-layers. As soon as it is sexually mature single cells of the wall become female egg-cells, or become male sperm-cells, or seed-cells; the former grow very large, as they form a considerable number of yolk granules in their protoplasm (Fig. 181, *e*); the latter, on the contrary, by continued division, become very small, and modify into movable "pin-shaped" spermatozoa (Fig. vol. i. p. 173). Both kinds of cells sever themselves from their birthplace, the primary germ-layers, fall either into the surrounding water or into the intestinal cavity, and there unite by amalgamation. This is the very important process of the fertilization of the egg-cell by the sperm-cell. (Fig. 18, vol. i. p. 175.)

These simplest processes of sexual reproduction exhibited at the present time in the lowest Plant Animals, especially in the Chalk Sponges and Hydroid Polyps, teach us of several extremely important and significant facts. In the first place, we learn, that for sexual reproduction in its simplest form, nothing more is required than the blending or amalgamation of two differing cells, a female egg-cell and a male sperm-cell, or seed-cell. All other circumstances, and all the other extremely complex phenomena, accompanying the act of sexual reproduction in higher animals, are of a subordinate and secondary character, and have only attached themselves secondarily to the simplest primary process of copulation or fertilization.

arisen by differentiation. But, now, if we consider t an extraordinarily important part is everywhere ed by the relation of the two sexes in organic nature, e vegetable kingdom, as in animal human life; how the reciprocal nation and attraction of the sexes, gives the impetus of the most ed and remarkable processes, is, one of the most important anical causes of the highest rentiation in life;—if we consider we cannot over-estimate this re- ng of "love" to its primitive e, to the power of attraction be- n two differing cells. Every- e throughout animated nature

G. 315.—Longitudinal section through a hysema (*Gastræada*). The egg-cells (*e*) are ed epithelial cells of the entoderm (*g*), e freely in the primitive intestinal cavity , mouth-opening; *h*, exoderm.

greatest results proceed from this most insignificant . It is only necessary to think of the part played in re by the flowers, the reproductive organ of flowering s; or of the multitude of wonderful phenomena d by sexual selection in animal life; or, finally, of the rtant influence exerted by love on human life: the coa- ce of two cells is everywhere the single, original lling motive; everywhere this apparently trivial pro-

cess exerts the greatest influence on the development
most varied circumstances. We may, indeed, asse
no other organic process can be, even remotely, comp
this in extent and intensity of differentiating effect.
is not the Semitic myth of Eve, who seduced Ad
knowledge, and is not the old Greek legend of Par
Helen, and are not very many other famous fictions,
the poetical expression of the immeasurable influence,
love, in connection with "sexual selection,"[86] has e
ever since the differentiation of the two sexes, on th
gress of the world's history? All other passions that
the human breast are in their combined effects f
powerful than love, which inflames the senses and fo
understanding. On the one hand, we gratefully glori
as the source of the most splendid creations of art;
noblest productions of poetry, of plastic art and of
we reverence in it the most powerful factor in
civilization, the basis of family life, and, conseque
the development of the state. On the other hand,
in it the devouring flame which drives the unfortu
ruin, and which has caused more misery, vice, an
than all the other evils of the human race taken t
So wonderful is love, and so immeasurably importa
influence on mental life, on the most varied function
medullary tube, that in this point, more than in an
"supernatural" causation seems to mock every
explanation. And yet, notwithstanding all this, t
parative history of evolution leads us back very cle
indubitably to the oldest and simplest source of
the elective affinity of two differing cells: the sp
and the egg-cell.

Just as the lowest Plant Animals exhibit this most ple origin of the complex phenomena of reproduction, in the second place, they reveal the highly important t, that the earliest and most primitive sexual relation s hermaphroditism, and that the separation of the sexes ginated from this only secondarily (by division of labour). rmaphroditism is prevalent in lower animals of the most ferent groups; in these, each single individual, when xually mature, each person, contains male and female xual cells, and is, therefore, capable of self-fertilization d self-reproduction. Thus, not only in the lowest Plant imals just mentioned (the Gastræads, Chalk-sponges, d many Hydroid Polyps) do we find egg-cells and erm-cells united in one and the same person; but any Worms (for example, the Ascidians, Earth Worms d Leeches), many Snails (the common garden Snail), and any other invertebrate animals are also hermaphrodite. ll the earlier invertebrate ancestors of man, from the astræada up to the Chordonia, must also have been hermaphrodite. So, probably, were also the earliest Skulled Animals (Figs. 52–56, *e*, *h*, vol. i. p. 256). One extremely weighty piece of evidence of this is afforded by the remarkable fact, that even in Vertebrates, in Man as well as other Vertebrates, the original rudiment of the sexual organs is hermaphrodite. The separation of the sexes (*Gonochorism*), the assignment of the two kinds of sexual cells to different individuals, originated from hermaphroditism only in the farther course of tribal history. At first, male and female individuals differed only in the possession of the two kinds of cells, but in other respects were exactly alike, as is now the case in the Amphioxus and the Cyclostoma.

Not until a later period, by the law of sexual selecti brilliantly elucidated by Darwin, were developed th called "secondary sexual characters," that is, tho ferences in the male and female sexes which are exhi not in the sexual organs themselves, but in other pa the body (for example, the beard of the man, the bre the woman).[36]

The third important fact, taught us by the lower Animals, refers to the earliest origin of the two ki sexual cells. For, as in Gastræads, and in many Spong Hydroids, in which we meet with the simplest rudi of sexual differentiation, the whole body consists thro life only of the two primary germ-layers, the two ki sexual cells can, therefore, only have originated fro of the two primary germ-layers. This simple disco of extreme importance, because the question of th origin of the egg-cells as well as of the sperm-cells higher animals—and especially in Vertebrates—p unusual difficulties. In these animals it usually as if the sexual cells developed, not from one of t primary, but from one of the four secondary germ If, as most authors assume, they do originate fr middle-layer, or mesoderm, the fact is due to an onto heterotopism, to a displacement in position. (Cf. vol. i Unless the unjustifiable and paradoxical assumptio the sexual cells are of entirely different origin in the and in the lower animals, is accepted, we are compe derive them originally (phylogenetically), in the forme the latter, from one of the two primary germ-layers. then be assumed that these cells of the skin-layer the intestinal layer, which must be regarded as the

enitors of the sperm-cells and of the egg-cells, with-
, during the separation of the skin-fibrous layer from
skin-sensory layer, or of the intestinal-fibrous layer
the intestinal-glandular layer, into the body-cavity
ma), which was in process of formation; and that
thus acquired the internal position between the two
ous layers, which appears as their original position,
en the sexual cells first become distinct in the vertebrate
bryo. Otherwise, we should be obliged to accept the
probable polyphyletic hypothesis, that the origin of the
g-cells and sperm-cells is different in the higher and in
e lower animals, that their origin in the former is inde-
ndent of that in the latter.

If we, accordingly, derive the two kinds of sexual cells
om the two primary germ-layers in man as in all other
imals, the farther question arises: Did the female egg-
lls and the male sperm-cells develop from both primary
erm-layers, or from one only? and, in the latter case, from
hich of the two? This important and interesting question
s one of the most difficult and obscure problems in the
history of evolution, and, up to the present moment, no full
and clear solution has been attained. On the contrary,
the most opposite answers are given to it even yet by
naturalists of note. Among the various possible solutions
only two have been generally considered. It has been
supposed that both kinds of sexual cells originally de-
veloped from the same primary germ-layer, either from the
skin-layer or the intestinal layer; but almost as many and
as able observers have accepted the one as the origin as
the other. Quite recently the Belgian naturalist, Eduard
van Beneden, has asserted, on the contrary, that the egg-cells

originate from the intestinal layer, the sperm-cells fr
skin-layer.[195] In Gastræads, Sponges, and Hydro-
this appears really to be the case. The development
sexual differences, which is so rich in results, m
cordingly, have commenced even during the differe
of the two primary germ-layers in the simplest and
Plant Animals; the exoderm would be the male germ
the entoderm, the female. If this discovery of Van B
is established and proves to be a universal law, Biolo
gain a most pregnant advance; for not only would
contradictory empiric explanations be answered, but
path would be opened for philosophic reflection on
the most important of biogenetic processes.

If we now trace the Phylogeny of the sexual
in our earliest Metazoic ancestors further, as it is in
at the present time, in the Comparative Anato
Ontogeny of the lowest Worms and Plant Anim
note, as the first advance, the accumulation of the
both sexes into definite groups. While in Spon
the lowest Hydra-Polyps single scattered cells separ
the cell-layers of the two primary germ-layers, and
isolated and free sexual cells, in the higher Plant
and Worms we find these same cells associated a
lected into groups of aggregate cells, which are,
forward, called "sexual glands," or "germ-glands" (*g*
It is only now that we can speak of sexual organs
morphological sense. The female germ-glands wh
such, in their simplest form constitute a mass of
genous egg-cells, are the ovaries (*ovaria*, or *oophor*
211, *e*, p. 198). The male germ-glands, which i
primitive form also consist merely of a mass of sper

he testes (*testiculi*, or *orchides*; Fig. 211, *h*). We find ovaries and testes in this earliest and simplest shape only in many Worms (*Annelida*) and Plant Animals, also in the lowest Vertebrates, in the Skull-less Animals *rania*). In the anatomy of the Amphioxus we found the ries of the female and the testes of the male consisting wenty to thirty elliptic or roundly four-cornered simple s, of small size, attached to the inside of the gill-cavity each side of the intestine. (Cf. vol. i. p. 425.)

Only a single pair of germ-glands, lying far down in the or of the body-cavity (Fig. 316, *g*), exist in all Skulled imals (*Craniota*). The first traces of these appear in the lom-epithelium. Probably, in this case also, the male erm-cells originate from the skin-layer, the female egg-lls, on the contrary, from the intestinal layer. The earliest aces are visible in the embryo at the point where the kin-fibrous layer and the intestinal-fibrous layer meet in he middle plate (mesentery-plate) (Fig. 318, *mp*, p. 408). At this very important point in the cœlom-wall, where the ndocœlar (or visceral cœlom-epithelium) merges into the exocœlar (or parietal cœlom-epithelium), in the embryo of Man and the other Skulled Animals a small aggregation of cells becomes visible, at a very early period, and this, according to Waldeyer,[196] we may call the "germ-epithelium," or (corresponding with the other plate-shaped rudiments of organs) the sexual plate (Fig. 316, *g*; Plate IV. Fig. 5, *k*). The cells of this germ-plate, or sexual plate (*lamella sexualis*) are essentially distinguished by their cylindrical form and by their chemical constitution from the other cells of the cœlom; they are of quite different significance from the flat cells of the "serous cœlom-epithelium" which line the

remainder of the body-cavity (*cœloma*). Of these lat
the true cœlom-cells—those which invest the int
tube and the mesentery ("*endocœlar*") originate fro

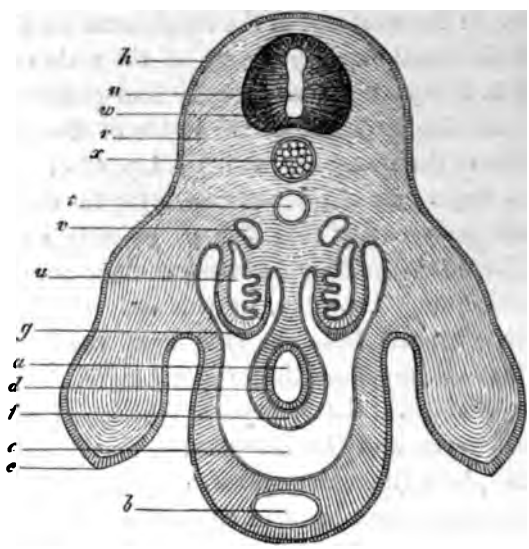


FIG. 316.—Transverse section through the pelvic region and limbs of an embryo Chick in the fourth day of incubation, enlarg 40 times: *h*, horn-plate; *w*, medullary tube; *n*, canal of the m tube; *u*, primitive kidneys; *x*, notochord; *e*, hind limbs; *b*, allant in ventral wall; *t*, aorta; *v*, cardinal veins; *a*, intestine; *d*, in glandular layer; *f*, intestinal-fibrous layer; *g*, germ-epithelium; muscles; *c*, body-cavity, or Cœlom. (After Waldeyer.)

intestinal-fibrous layer (in Fig. 5, Plate IV., coloured those which line the inner surface of the external v the abdomen ("*exocœlar*") are, on the contrary, the p of the skin-fibrous layer (coloured blue in Fig. 5, Plat but the sexual cells which make their appearance boundary line between the two forms of cœlom-cell

ch insert themselves, to a certain extent, between the cœlar and the exocœlar, there forming the germ-e, cannot be referred either to the intestinal-fibrous r or to the skin-fibrous layer, but directly to the two ary germ-layers; for there are important grounds for osing that even the first rudiment of the sexual plate is, ably, hermaphroditic, and that this "sexual epithelium" ible, in Man and all other Vertebrates, between the exo-ar and the endocœlar) represents a primæval and simple naphrodite gland. (Cf. vol. i. p. 256, Figs. 52–56, *e*, *h*.) inner half of this, in contact with the intestinal-fibrous er, which is derived from the intestinal-glandular layer, ld be the rudiment of the ovary; its outer half, in tact with the skin-fibrous layer, which originates from intestinal-glandular layer, would be the rudiment of the tes. This is, of course, only conjectural.

We ought, accordingly, to distinguish two different ual plates or germ-epithelia; the female sexual plate, a duct of the intestinal layer, which gives rise to the ary-epithelium—the mother cells of the ova ("ovary-te"); and the male sexual plate, lying externally over the mer, and which is a product of the skin-layer, from which ginates the testes-epithelium—the mother cells of the rm-threads ("testes-plate"); but even the first recog-able rudiments of the two sexual plates appear, indeed, intimately associated in the human embryo and in those the higher Vertebrates, that hitherto they have been re-ded as a single, undifferentiated, common rudiment of an an; and it is still possible that the two kinds of sexual nds arise by secondary differentiation from a common liment.

Though we must recognize the formation of t
kinds of sexual cells, and in their union at fertiliz
the one essential act of sexual reproduction, yet, in th
majority of animals, other organs exist which al
part in the act of fertilization. The most impor
these secondary sexual organs are the exit-ducts
serve to conduct the mature sexual cells out of the
and, next to these, the copulative organs, which t
the fertilizing sperm from the male person to the
in which the eggs are situated. These latter orga
only in the higher animals of various tribes, and are
widely distributed than the exit-ducts. Even these
however, are only of secondary formation, and are w
in many animals of the lower groups. In these, as
the mature sexual cells are simply ejected from th
In some cases they pass out directly through th
skin-covering (as in the Hydra and many of t
droidea); in other cases, they enter the stomach-
and are ejected through the mouth-opening (in Gas
Sponges, and other Hydroid Polypes and Coral An
in yet other cases, they enter the body-cavit
pass out through a special aperture in the ventr
(*porus genitalis*). The latter is the case in many
and even in a few lower Vertebrates (Cycloston
a few Fishes). These indicate the earliest condit
this matter as it was in our ancestors. On the
hand, in all higher, and most lower Vertebrates (
in most higher Invertebrates) special tube-shaped
ducts from the sexual cells, or sexual ducts (*gono*
are present in both sexes. In the female these conv
egg-cells out from the ovaries, and hence they hav

egg-ducts (*oviductus*, or *tubæ fallopiæ*). In the ex these tubes convey the sperm-cells from the testes, ence they are called sperm-ducts (*spermaductus*, or *leferentia*).

e original, genetic condition of these two outlets ctly the same in Man as in all higher Vertebrates, in most Invertebrates it is entirely different; for in the latter the sexual ducts develop directly from xual glands, or from the external skin, or from the in- l canal, in Vertebrates an organ-system is employed e conveyance of the sexual products; one which origin- ad a very different significance and function—the y system, or urinary organs. The original, primary func- f these organs is simply to eliminate useless matter he body in a liquid form. The liquid product of this ion is called the urine, and is discharged either directly gh the external skin, or through the last section of the ine. The tube-shaped "urinary ducts" only second- bsorb the sexual products also and convey them out; hus become "urogenital ducts" (*ductus urogenitales*). emarkable secondary combination of the urinary and xual organs into a common "urogenital apparatus," or enital system," is highly characteristic of the higher brates. In the lowest of these it is, however, wanting, on the other hand, it is found in the higher Ringed s (*Annelida*). To estimate this rightly, we must first at the comparative economy of the urinary organs hole.

e kidney system or urinary system (*systema uro- um*) is one of the earliest and most important organ- ns in the differentiated animal body, as has already

been incidentally mentioned. (Cf. Chapter XVII.) found almost universally distributed, not only in the h animal tribes, but even in the more primitive Worm Among the latter it even occurs in the lowest and imperfect known Worms—the Flat Worms (*Plathelmi* (Fig. 184, *nc*, p. 80). Although these accelomatous W have no body-cavity, no blood, no vascular system always have a kidney system. It consists of a p simple or of branched canals, lined by a layer of cells, absorb useless juices from the tissues and discharge through an external skin-opening (Fig. 184, *nm*). only the free-living Gliding Worms (*Turbellaria*), bu the parasitic Sucking Worms (*Trematoda*), and ev still more degraded Tape Worms, which, in conse of their parasitic habit of life, have lost their int canal, are all provided with these "kidney canals" or tive kidneys. Usually these canals in the Worms are excretory organs, and in former times they used to be water-vessels. Phylogenetically they must be regar highly-developed pouch-like skin-glands resemblin sweat-glands of Mammals, and, like these, developed the skin-sensory layer. (Cf. Fig. 210, *n*, p. 198, and Fi p. 202.)

While in these lowest unsegmented Worms only a pair of kidney ducts is present, in the higher segm Worms these ducts exist in greater numbers. In R Worms (*Annelida*), in which the body is composed great number of segments, or metamera, a pair of primitive kidneys (hence known as segmental orga canals) exists in each separate segment. In this case, the canals are very simple tubes, which, on account of

iled or looped form, are called "coiled canals." To the imary, external aperture in the outer skin, originally one present, a secondary, internal aperture into the body-ivity (*cœloma*) is now added. This opening is provided ith vibratory cilia, and is thus enabled to absorb the ecretional juices from the body-cavity and to discharge hem from the body. Now in these Worms also the sexual ells, which develop in the simplest form upon the inner urface of the abdominal wall, pass, when mature, into the cœlom, are drawn into the internal, funnel-shaped ciliated openings of the kidney canals, and are carried out of the body with the urine. Thus the urine-forming "coiled canals," or "primitive kidneys," serve, in the female Ringed Worms, as "oviducts," and, in the male, as "sperm-ducts."

It would of course be most interesting to know the condition, on this point, of the Amphioxus, which, standing midway between Worms and Vertebrates, affords us so much valuable information. Unfortunately this animal, for the present, affords no solution of this matter. At present we know nothing certainly as to the relation between the urinary and the sexual organs of the Amphioxus. Some zoologists assert that this animal has no kidneys; others regard the two long "side canals" as atrophied primitive kidney ducts (Fig. 152, *S*, vol. i. p. 423); yet others consider certain glandular epidermis-swellings on the inner surface of the gill-cavity to be rudimentary kidneys. Most probably, a great reversion has affected the original primitive kidney canals in the Amphioxus, amounting perhaps to their entire phylogenetic loss.

Very interesting inferences may be drawn from the Vertebrates of the next stage—the Monorhina, or Cyclos-

toma. Although both orders of this class—the Myx as well as the Petromyzontes—possess developed, secreting kidneys, these organs do not in this case s carry away the sexual cells. These cells pass direct the germ-glands into the cœlom, and are discharged t a posterior aperture in the abdomen. The condition primitive kidneys in these is, however, very interesti throws light on the complex structure of the higher Vert In the first place, in the noides (*Bdellostoma*) we find tube, the primitive kidne (*protureter*, Fig. 317, *a*), o side. This opens internall the cœlom through a ciliated shaped aperture (as in Worms); it opens externally t an opening in the outer sk great number of small hor tubes ("segmental canals," or

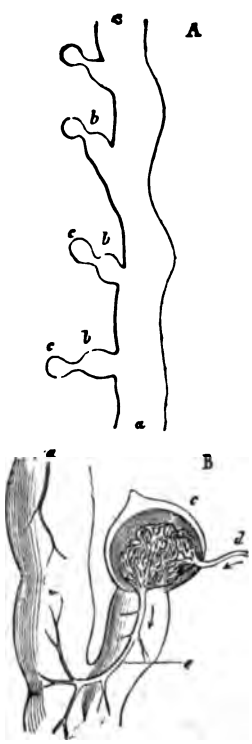


FIG. 317.—*A*. Portion of kidney lostoma: *a*, primitive kidney duct *reter*); *b*, segmental canals, or p urine canals (*tubuli uriniferi*); *c*, vesicles (*capsulæ Malphigianæ*).— tion of the same, much enlarged: *c*, vesicle, with the *glomerulus*; *d*, app artery; *e*, retreating artery. (After J Müller.)

tive urine tubes) open on its inner side. Each o terminates in a blind, vesicular capsule (*c*) enclo

ot of blood-vessels (*glomerulus*, an arterial net, Fig. 17, *B*, *c*). Afferent arterial branches (*vasa afferentia*) convey arterial blood into the coiled branches of the "*glomerulus*" (*d*), and efferent arterial branches (*vasa efferentia*) again carry it out of the *glomerulus* (*e*).

In Primitive Fishes (*Selachii*) also there is a longitudinal series of segmental canals, which open outwardly in the primitive kidney ducts. The segmental canals (a pair in each metameron of the central part of the body) open, in this case, freely into the body-cavity, through a ciliated funnel (as in Ringed Worms, or Annelids). A part of this organ forms a compact primitive kidney, while the rest is employed in the formation of the sexual organs.

The primitive kidney in the embryo of Man and in that of all other Skulled Animals (*Craniota*) is first formed in the same simple shape which persists throughout life in Myxinoides, and partly in Selachii. We found this primitive organ in the human embryo at that early period just succeeding the separation in the skin-sensory layer, of the medullary tube from the horn-plate, and the differentiation, in the skin-fibrous layer, of the notochord, the primitive vertebral plate, and the skin-muscle plate. As the first rudiment of the primordial kidneys, a long thin, thread-like string of cells, which is soon hollowed out into a canal, appears in this case, on each side, immediately below the horn-plate; this extends in a straight line from front to back, and is plainly seen in the cross section of the embryo (Fig. 318) in its original position in the space between the horn-plate (*h*), the primitive vertebræ (*uw*), and the skin-muscle plate (*hpl*). The first origin of this primitive kidney duct is still a matter of dispute, some ontogenists

referring it to the horn-plate, others to the primitive which tebral plate, and yet others to the skin-muscle plate. each bably its earliest (phylogenetic) origin is to be found in the semi-skin-sensory layer; but it very soon quits its superficial

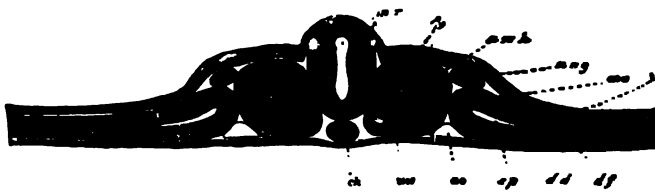


FIG. 318.—Transverse section through the embryo of a Chick, on the second day of incubation: *h*, horn-plate; *m*, medullary tube; *umg*, primitive kidney duct; *ch*, notochord; *uw*, primitive vertebral cord; *hpl*, skin-fibrous layer; *df*, intestinal-fibrous layer; *mp*, mesentery-plate, or middle plate (point of attachment of the two fibrous layers); *sp*, body-cavity (*cœloma*); *ao*, primitive aorta; *dd*, intestinal-glandular layer. (After Kölliker.)

position, passes inward, between the primitive vertebral plates and the side plates, and finally lies upon the inner surface of the body-cavity. (Cf. Figs. 66–69, *u*, vol. i. p. 277, and Figs. 95–98, p. 319; also Plate IV. Figs. 3–6, *u*.) While the primitive kidney duct is thus making its way inward, on its inner and under side appear a large number of small horizontal tubes (Fig. 319, *a*), exactly corresponding to the segmental canals of the Myxinoides (Fig. 317, *b*). Like the latter, these are, probably, originally protuberances of the primitive kidney ducts (Fig. 316, *u*). At the blind, inner end of each of the primitive urinary tubes an arterial glomerulus is formed, which grows into this blind end from within, forming a "vascular coil." The glomerulus to a certain extent expands the bladder-like blind end of the small urinary tubes. As the primitive urinary tubes

ich are, at first, very short, grow longer and broader, ch of the two primitive kidneys assumes the form of a ni-pinnate leaf (Fig. 320). The urinary tubes (*u*) repre-

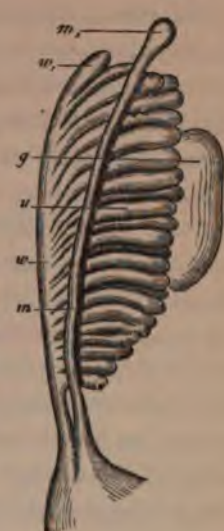


FIG. 319.—Rudimentary primitive kidney of embryonic Dog. The posterior portion of the body of the embryo is seen from the ventral side, covered by the intestinal layer of the yelk-sac, which has been torn away, and thrown back in front in order to show the primitive kidney ducts with the primitive kidney tubes (*a*) : *b*, primitive vertebræ; *c*, dorsal medulla; *d*, passage into the pelvic intestinal cavity. (After Bischoff.)

FIG. 320.—Primitive kidney of a human embryo: *u*, the urine-tubes of the primitive kidney; *w*, Wolffian duct; *w'*, upper end of the latter (Morgagni's hydatid); *m*, Müllerian duct; *m'*, upper end of the latter (Fallopian hydatid); *g*, hermaphrodite gland. (After Kobelt.)

sent the tissue and the primitive kidney duct (*w*) the mid-rib. On the inner margin of the primitive kidney the rudiment of the hermaphrodite sexual gland already

appears as a body of considerable size. The posterior end of the primitive kidney duct opens into the lower extremity of the last section of the rectum, so that this organ becomes a cloaca. But this opening of the primitive kidney duct into the intestinal canal must be regarded, phylogenetically, as a secondary condition. Originally, as is indicated clearly in the Cyclostoma, they issued through the external abdominal skin, quite independently of the intestinal canal, thus proving their early phylogenetic origin from the horn-plate, as outer skin glands.

While in the Myxinoides the primitive kidneys permanently retain this simple form, as they do partially in Primitive Fishes (*Selachii*), in all other Craniota it appears only temporally in the embryo, as the ontogenetic reproduction of the primordial phylogenetic condition. In these Skulled Animals the primitive kidney, by vigorous growth, increases in length, and by the increase in number and the coiling of the urinary tubes, very soon assumes the form of a large compact gland, of oblong, oval, or spindle-shaped form, which extends longitudinally through the greater part of the body-cavity (*cœloma*) of the embryo (Figs. 123, *m*, 124, *m*, vol. i. p. 370). In this case, it lies near the middle line, directly under the primitive vertebral column, and extends from the region of the heart to the cloaca. The right and left primitive kidneys lie parallel and close together, being separated only by the mesentery, that narrow, thin lamella which connects the central intestine with the lower surface of the primitive vertebral column. The excretory duct of each primitive kidney, the protureter, traverses the lower and outer side of the gland in a posterior direction, and opens into the cloaca, close to the root of the allantois; at

later period, it opens into the allantois itself (Fig. 136, *o*, vol. i. p. 381).

The primitive kidney (primordial kidney) in the embryo of Amniota was formerly called the "Wolffian body," also the "Okenian body." In all cases it acts for a time as a true kidney, draining and secreting the useless fluids of the embryonic body, and discharging them into the cloaca and then into the allantois. The "primitive urine" collects in the latter organ, and hence the allantois in the embryo of man and of the other Amniota acts as a real urinary bladder, or "primitive urinary sac;" yet it is in no way genetically connected with the primitive kidneys, but is rather, as we have already seen, a pouch-like protuberance of the anterior wall of the terminal intestine (Fig. 135, *u*, vol. i. p. 380). The allantois is, therefore, a product of the intestinal layer, while the primitive kidneys are a product of the skin-layer. Phylogenetically we must conceive that the allantois originated as a pouch-shaped protuberance of the cloacal wall resulting from the distension caused by the collection in the cloaca of the primitive urine secreted by the primordial kidneys. It is, originally, a blind sac belonging to the rectum (Plate V. Fig. 15, *hb*). The true urinary bladder of Vertebrates, evidently, first appeared in Dipneusta (in the Lepidosiren), and was thence transmitted, first to the Amphibia, and then to the Amniota. In the embryo of the latter it protrudes far out of the yet unclosed abdominal wall. Many Fishes, indeed, also possess a so-called urinary bladder. But this is merely a local distension in the lower section of the primitive kidney ducts, and hence, both in origin and in constitution, is essentially distinct from the true urinary bladder. The two structures

are only physiologically comparable; they are, the
analogous, as having the same function; morpholog
however, they are not to be compared, or are not l
logous.[188] The false urinary bladder in Fishes is a
duct of the primitive kidney duct, therefore of the
layer; the true urinary bladder in Dipneusta, A
bia, and Amniota is, on the contrary, a blind-sac o
terminal intestine, and hence a product of the int
layer.

In all low Skulled Animals (*Craniota*), without a
(in Cyclostoma, Fishes, Dipneusta, and Amphibi
urinary organs remain in an inferior stage of develo
in so far as the primitive kidneys (*protonephra*),
much modified, here act permanently as urine-se
glands. In the three higher vertebrate classes, inclu
the term Amnion Animals, on the contrary, this is t
only for a short period during early embryonic life
permanent, or secondary kidneys (*renes*, or *metan*
which are peculiar to these three classes, are very
developed. These originate, not (as was long belie
the authority of Remak) as entirely new, indep
glands of the intestinal tube, but from the posterior
of the primitive kidney duct (*protureter*). From the
near where it opens into the cloaca, a simple pouc
secondary kidney duct—grows out, and this increase
siderably in length forwards; from the blind, up
anterior portion of this the permanent kidney orig
precisely as the primitive kidney originates from th
mitive kidney duct. The secondary kidney duct giv
to a number of small blind tubes—the secondary u
tubes — and the blind capsule-shaped ends of

occupied by vascular coils (*glomeruli*). The further growth of these tubes results in the compact secondary kidney, which, in Man and most higher Mammals, acquires the well-known bean-like form; in the lower Mammalia, Birds and in Reptiles, on the other hand, it is separated into several lobes. The lower, or posterior part of the permanent kidney duct retains the form of a simple canal, widens, and thus forms the permanent urine duct (*ureter*). At first this canal, yet united with the last section of the primitive kidney duct, discharges into the cloaca; at a later period, it separates from the primitive kidney duct, and yet later from the rectum, and then it discharges into the permanent urinary bladder (*vesica urinaria*). The latter originates from the posterior, or lower part of the stalk of the allantois (*urachus*), which widens and becomes spindle-shaped before opening into the cloaca. The anterior, or upper part of the allantois-stalk, which passes in the abdominal wall of the embryo to the navel, afterwards disappears, a useless cord-shaped remnant alone remaining as a rudimentary organ: this is the single urinary-bladder navel-cord (*ligamentum vesico-umbilicale medium*). On the right and left of this, in the adult Man, there are two other rudimentary organs: the lateral urinary-bladder navel-cords (*ligamenta vesico-umbilicalia lateralia*). These are the obsolete cord-like remnant of the former navel-arteries (*arteriæ umbilicales*, vol. i. p. 400; Fig. 326, *a*).

Although in Man, as in all other Amnion Animals, the primitive kidneys are thus very early displaced by the secondary kidneys, and although the latter alone afterwards act as urinary organs, the former are not, however, altogether discarded. Indeed, the primitive kidney ducts acquire

a high physiological significance, as they modify int cretory ducts of the sexual glands. In all Amphibia Gnathostomi—therefore in all Vertebrates from Fish to Man—at a very early period, a second similar appears in the embryo at the side of each primitive k duct. This canal is commonly called, after its disco Johannes Müller, "Müller's duct" (*ductus Mülleri*), the earlier, primitive kidney duct is distinguished a "Wolffian duct" (*ductus Wolffii*). The actual orig Müller's duct is still undetermined; Comparative Ana and Ontogeny seem, however, to indicate that it pro by differentiation from the Wolffian duct. It is, prob most correct to say, that the original (primary) pri kidney duct breaks up by differentiation (or fission two secondary, similar ducts; these are the Wolffia

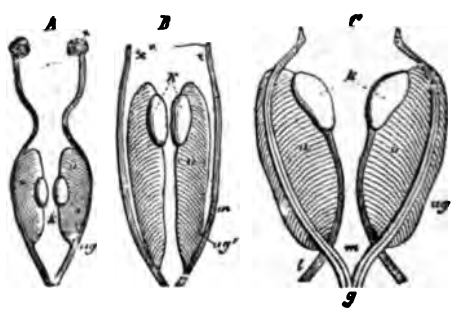


FIG. 321.—Primitive kidneys and rudiments of the sexual organs *B*, of Amphibia (Frog larvæ); *A*, earlier, *B*, later condition. *C*, of mal (embryo of Ox): *u*, primitive kidneys; *k*, sexual glands (rudi testes and ovaries). The primary primitive kidney duct (*ug* in separates (in *B* and *C*) into the two secondary primitive kidney du Müllerian duct (*m*) and the Wolffian duct (*ug'*), which unite behin genital cord (*g*); *l*, groin-cord of the primitive kidneys. (After Geg

[üllerian ducts. The latter (Fig. 320, *w*) lies imme-
y inside the former (Fig. 320 *m*). Both open pos-
y into the cloaca.

scure and uncertain as
origin of the Müllerian
olffian ducts, their later
y is clear and definite.
Double-nostrilled (*Am-*
na) and Jaw-mouthed
hostomi) animals, from
ive Fishes up to Man,
olffian duct becomes the
uct, and the Müllerian
the oviduct. In each
ly one of these is per-

. 322, 323.—Urinary and sexual
f an Amphibian (Water-Newt,
n). Fig. 322 (*A*), female;
(*B*), male: *r*, primitive kid-
, ovary; *od*, egg-duct and
duct, both formed from the
n duct; *u*, primitive urinary
ting, in man, also as seed-
)—opening below into Wolff's
); *ms*, ovary-mesentery (*mes-*
). (After Gegenbaur.)

; the other entirely disappears, or leaves only a
it as a rudimentary organ. In the male sex, in
the two Wolffian ducts become sperm-ducts, certain
nts of the Müllerian duct are often found, which
l call "Rathke's canals" (Fig. 323, *c*). In the female
here, on the contrary, the two Müllerian ducts

become oviducts, traces of the Wolffian ducts remain, a
are known as "Gartner's canals."

FIGS. 324–326.—Urinary and sexual organs of an embryonic Or.
324, of female embryo of 1½ inch in length; Fig. 325, of male emb
of 2½ inches in length; Fig. 326, of female embryo of 2½ inches in leng
w, primitive kidney; *wg*, Wolff's duct; *m*, Müller's duct; *m'*, upper en
he latter (opened at *t*); *i*, lower thickened end of the same (radin
of uterus); *g*, genital cord; *h*, testes (*h'*, lower, *h''*, upper testis-co
o, ovary; *o'*, lower ovary-cord; *i*, groin-cord of the primitive kid
d, diaphragm-cord of the primitive kidney; *n*, permanent kidneys (b
these the S-shaped urine-duct; between the two the rectum); *v*, u
bladder; *a*, navel-artery. (After Kölliker.)

The most interesting facts in reference to this rema
able development of the primitive kidney ducts and t
union with the sexual glands are exhibited in Amphi
(Figs. 321–323). The first rudiment of the primitive kid
ducts and their differentiation into the Müllerian

ian ducts is identical in both sexes, as is the case in mbryos of Mammals (Fig. 321, *C*, Fig. 324). In the e Amphibia the Müllerian duct on each side develops large ovary (Fig. 322, *od*), while the Wolffian duct acts nently as a urinary duct (*u*). In the male, on the ary, the Müllerian duct persists only as a rudimentary , without functional significance, as Rathke's canal 323, *c*); the Wolffian duct serves, in this case also, as a ry duct, but also as a sperm or seed duct, the seminal (*ve*) from the testes (*t*) entering the upper part of the tive kidneys, and there uniting with the urinary canals. Mammals these conditions, persistent in Amphibia, are ly traversed by the embryo in an early period of its opment (Fig. 321, *C*). The primitive kidneys, which n-amnionate Vertebrates persist throughout life as the -secretory organ, are superseded by the secondary ys. The actual primitive kidneys disappear almost ly in the embryo at an early period, leaving but small . In the male Mammal the supplementary testis *idymis*) develops from the upper part of the primitive y; in the female the same part gives rise to a useless entary organ, the supplementary ovary (*parovarium*). the female Mammal the Müllerian ducts undergo very lerable changes. The actual ovaries develop only from per part; the lower part widens out into a spindle- d pouch, with a thick, fleshy wall, within which the zed egg develops into the embryo. This pouch is the (*uterus*). At first the two uteri are perfectly te, and open on each side of the urine-bladder (*vu*) the cloaca, as is yet permanently the case in the living Mammals, the Beaked Animals (*Ornithostoma*);

but even in Pouched Animals (*Marsupialia*) a
forms between the two Müllerian ducts, and in
Animals they coalesce below with the rudimentar
ducts, forming with then
"sexual cord" (*funicul*
talis). But the original
dence of the two part
uterus, and of the tw
canals which proceed out
lower extremities, persist
lower Placental Animals,
the higher members of
group, these organs
coalesce to form one sin
The process of coales
vances steadily from
from behind) upwards
wards). While in many
Animals (*Rodentia, e.g.*,
Squirrels) two separate
into the vagina canal w

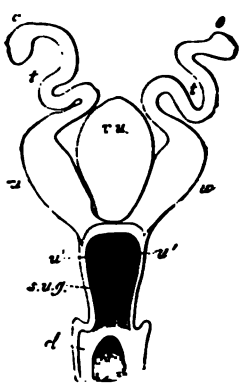


FIG. 327.—Female sexual organs of a Beaked Animal (*Ornithorhynchus*, Figs. 195, 196): *o*, ovaries; *t*, oviduct; *u*, uterus; *sug*, urinary sexual cavity (*sinus urogenitalis*); the two parts of the uterus open into this at *u'*: *cl*, cloaca. (After Gegenbaur.)

already become simple, in other Gnawing Animal
in Beasts of Prey, Whales, and Hoofed Animals (*U*
the lower halves of the two uteri are already c
their upper halves (the so-called horns, "*cornua*") r
distinct ("*uterus bicornis*"). In Bats and Semi-a
upper horns are very short, while the unified lo
becomes longer. Finally, in Apes, as in Man, the
of the two parts is complete, one simple pear-shape
pouch alone remaining, and into this the oviducts
each side.

ı the male Mammal also, a similar coalescence of the portion of the Müllerian and Wolffian ducts takes In this case also, these ducts form a single "sexual (Fig. 325, *g*), which likewise opens into the original ry sexual cavity (*sinus urogenitalis*), which develops the lower part of the urinary bladder (*v*). While, ver, in the male Mammal the Wolffian ducts develop the permanent sperm-ducts, only very slight traces of Müllerian ducts remain as rudimentary organs. The remarkable of these is the "male uterus" (*uterus ulinus*), which originates from the lowest, coalescent ›n of the Müllerian ducts, and which is homologous the female uterus. It forms a small flask-shaped e, entirely without physiological significance, which into the urinary tubes between the two sperm-ducts he prostatic lobes (*vesicula prostatica*).

ıe internal sexual organs in Mammals undergo very iar modifications in point of position. At first the glands, in both sexes, lie deep down in the ventral ', on the inner side of the primitive kidneys (Figs. ', 321, *k*), attached to the vertebral column by a short ıtery (in the male, the *mesorchium;* in the female, *arium*). It is only, however, in Monotremes that this al position of the germ-glands is (as in lower Verte- es) permanent. In all other Mammals (Marsupials as ıs Placentals) these glands quit their place of origin ıake their way more or less downward (or towards the ior extremity), following the course of a cord which ls from the primitive kidney to the groin region of ›dominal wall. This is the groin-cord of the primitive y; in the male, the "Hunterian guiding-cord" (*guber-*

naculum testis) (Fig. 328, *M*, *gh*); in the female, the r
uterus-cord (Fig. 328, *F*, *r*). In the latter the ov
migrate more or less in the direction of the small pelvis

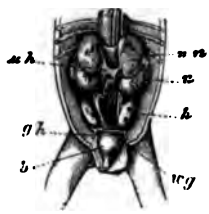


FIG. 328, *M*.

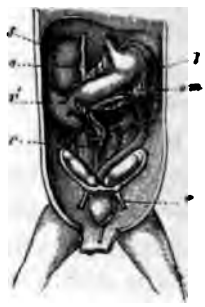


FIG. 328, *F*.

FIG. 328.—Original position of the sexual glands in the abdominal ca
of the human embryo (of three months). Fig. 328, *M*, male (natural si
h, testis; *gh*, the conducting-cord of the testis; *wg*, seed-duct; *b*, uri
bladder; *uh*, lower hollow vein (*vena cava*); *nn*, supplementary kidn
n, kidneys. Fig. 328 *F*, female (somewhat enlarged): *r*, round uterus-
(below this the urine-bladder, above it the ovary); *r'*, kidney; *s*,
plementary kidney; *c*, blind-intestine (*cæcum*); *o*, small net; *om*,
net (between the two is the stomach); *l*, spleen. (After Kölliker.)

even enter this. In the male the testis quits the abdom
cavity altogether, passing through the groin-canal,
enters a sac-shaped, distended fold of the external sk
covering. The coalescence of the right and left f
("sexual folds") gives rise to the testis-sac (*scrotum*).
various Mammals exhibit the various stages of this mi
tion. In the Elephant and in Whales the testes desc
very little, and lie below the kidneys. In many Gnaw
Animals (*Rodentia*) and Beasts of Prey (*Carnaria*) t
enter the groin-canal. In most higher Mammals they
down through this into the testis-sac; usually the wall

the groin-canal coalesce. When, however, this remains open, the testes are able to descend periodically (in the rutting season) into the testis-sac, returning again into the abdominal cavity (*e.g.*, in Pouched Animals or *Marsupialia*, Gnawing Animals, Bats, etc.).

Another peculiarity of Mammals is the formation of the external sexual organs which, as copulative organs, serve to carry the fertilizing sperm from the male into the female organism in the act of copulation. Organs of this sort are altogether wanting in most lower Vertebrates. In those which are aquatic (*e.g.*, Acrania, Cyclostoma, and most Fishes) the eggs and sperm are simply discharged into the water, and their coming together is the result of some lucky accident which in this way brings about impregnation. On the other hand, in many Fishes and Amphibia which bring forth their young alive, there is a direct transfer of the sperm from the male to the female organism; and this is the case in all Amniota (Reptiles, Birds, and Mammals). In these animals the urinary and genital organs always open originally into the lower part of the rectum, which thus forms a "cloaca" (p. 345); but among Mammals the cloaca is permanent only in the Beaked Animals (*Ornithostoma*), which have, on this account, been called Cloacal Animals (*Monotrema*, Fig. 327, *cl*). In all other Mammals a lateral partition wall develops in the cloaca (in the human embryo about the middle of the third month), by which the latter is separated into two cavities. The urinary sexual canal passes into the anterior cavity (*sinus urogenitalis*), and it is through this cavity alone that the urinary and sexual products are discharged, while the "anal cavity," which lies behind it, serves merely to eject the excrement through the

anus. Even before the appearance of this partition, i
Pouched Animals (*Marsupialia*) and Placental Ani
conical papilla—the sexual protuberance (*phallus*, Fi
A, *e*, *B*, *e*)—rises on the anterior part of the circumfere

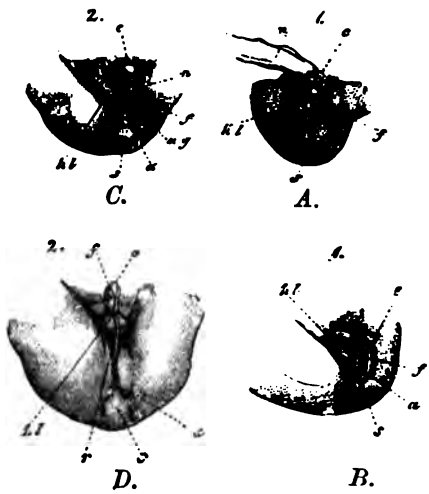


FIG. 329.—External sexual organs of the human embryo: *A* germ (in the eighth week; twice the natural size; with cloaca); *B* germ (in the ninth week; twice the natural size; anus distinct urogenital opening); *C*, female germ in the eleventh week; *D*, m in the fourteenth week; *e*, sexual protuberance (*phallus*); *f*, sexua *hl*, sexual folds; *r*, Raphe (point of union of the penis and *a*, anus; *ug*, urinary sexual opening; *n*, navel-cord; *s*, tail. (Afte Cf. Table XLIV., p. 431.

the cloaca-opening. The apex of this is swollen into (the "acorn," *glans*). On the under side appears a (*sulcus genitalis*, *f*), and on each side of the latter fold, or sexual fold (*hl*). The phallus is especially th of the "sexual sense," and over it are distributed the

s (*nervi pudendi*) which are especially concerned in
ıcing the sexual sensations (p. 238). In the male the
us develops into the masculine "*penis*" (Fig. 329, *D*, *e*);
e female it becomes the much smaller "*clitoris*" (Fig.
C, *e*); only in some Apes (*Ateles*) does this become un-
ly large. The "fore-skin" (*præputium*), in both
, also develops as a skin-fold from the anterior part of
ircumference of the phallus. In the male sexual furrow
lower side of the phallus receives the urogenital
, and, as a continuation of the latter, modifies, by the
scence of its two parallel edges, into a closed canal—
nale urinary tube (*urethra*). In the female this occurs
in a few instances (in some Semi-apes, Gnawing Animals
dentia, and Moles); as a rule the sexual furrow remains
and its edges are developed into the *labia minora*.
labia majora of the female develops from the two
lel skin-folds which appear on each side of the sexual
w. In the male these last folds coalesce, forming a
d sac, the testis-sac (*scrotum*). Occasionally this
scence does not take place, and the sexual furrow also
times remains open (*hypospadia*). In these cases the
nal male genitalia resemble the female, and this phe-
non has often been mistaken for hermaphroditism
do-hermaphroditism).[197]

'rom this and other cases of false "hermaphroditism,"
nuch less frequent cases of "true hermaphroditism" are
distinct. This exists only when the essential organs of
duction, both kinds of germ-glands, are united in one
idual. Either an ovary is then developed on the right,
ı testis on the left (or *vice versa*); or testes and ovaries
developed on both sides, one more, the other less

perfectly. As we have already seen that the orig rudiment of the sexual organs is really hermaphrodi all Vertebrates, and that the separation of the sexes is due to a one-sided development of this hermaphro rudiment, these remarkable cases offer no theoretic d culties. They very seldom, however, occur in Man and higher Vertebrates. On the other hand, we find orig hermaphroditism constant in some lower Vertebrates, some Fishes of the Perch kind (*Serranus*), and in Amphibia (*Bombinator* and in Toads). In these cases male has usually a rudimentary ovary at the uppe tremity of the testis; on the other hand, the female sometimes a rudimentary testis, without function. also occurs occasionally in Carp and some other Fi We have already seen how the original hermaphrodi is maintained in the excretory ducts, in Amphibia.

In the germ-history of the human urinary and se organs, the outlines of the history of human descent been faithfully maintained up to the present time. We trace their development in the human embryo step by in the same gradations as are exhibited, one after ano in the comparison of the urogenitals in Acrania, Cyclost Fishes, Amphibians, and then further, in the serie Mammals, in Cloacal Animals (*Monotremes*), Pou Animals (*Marsupialia*), and the various Placental Anir (Cf. Table XLIII.) All the structural peculiarities of urogenitals, distinguishing Mammals from other Ve brates, are also present in Man; and in all special cha teristics the latter resembles the Apes, and especially Anthropoid Apes. As evidence that the special peculiar of Mammals have been transmitted to Man, I will fin

briefly notice the similar manner in which the eggs are formed in the ovary. In all Mammals, the mature eggs are contained in peculiar vesicles, which, after their discoverer, Regner De Graaf (1677), are called the Graafian follicles. These were formerly regarded as the actual eggs, which were, however, discovered by Baer *within* the Graafian follicles (vol. i. p. 55). Each follicle (Fig. 330, *C*) consists of a round, fibrous capsule, which contains fluid and is coated by several layers of cells. At one point this cellular layer has a knob-like enlargement (*C*, *b*), and, there, surrounds the real egg (*C*, *a*). The mammalian ovary is, originally, a very simple oblong little body (Fig. 320, *g*), formed only of connective tissue and blood-vessels, and surrounded by a cell-layer (the epithelium of the ovary, or the female germ-epithelium). From this epithelium, cords of cells grow inward, into the connective tissue or "stroma" of the ovary (Fig. 330, *A*, *b*). Single cells of these cords increase in size and become egg-cells (primitive eggs, *A*, *c*); but the greater number of the cells remain small and form an enveloping and nutritive cellular layer (the follicle-epithelium) round each egg.

In Mammals the follicle-epithelium is at first one-layered (Fig. 330, *B*, 1), afterwards many-layered (*B*, 2). In all other Vertebrates, the egg-cell is, indeed, enclosed in a permanent covering of small cells, an egg-follicle; but only in Mammals does fluid accumulate between the growing follicle-cells, and thus extends the follicle into a round bladder of considerable size, on the inner wall of which the egg lies excentrically. In this point, as in his whole Morphology, Man unmistakably indicates his descent from Mammals.

FIG. 330, *A*.

FIG. 330, *B*.

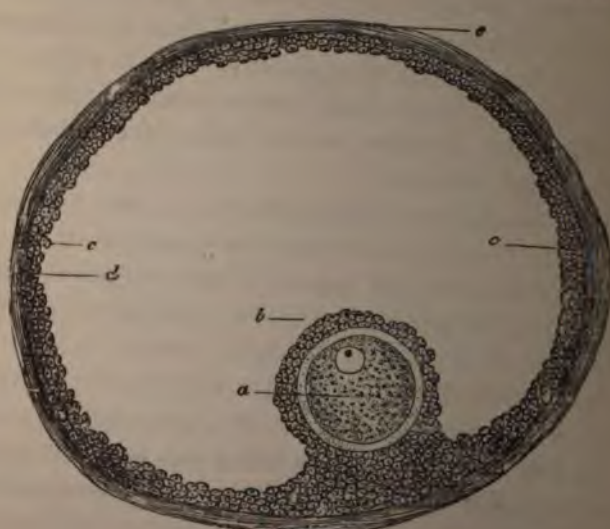


FIG. 330, *C*.

FIG. 330.—Development of human ovules within the female ovary.—*A.* Vertical section through the ovary of a new-born female: *a*, epithelium of the ovary; *b*, rudiment of an egg-cord; *c*, young eggs in the epithelium; longer egg-cord with the follicles; *e*, group of young follicles; *f*, single young follicle; *g*, blood-vessels in the connective tissue (*stroma*) of the ovary. In the cords the young primitive eggs can be distinguished from the surrounding cells of the follicle by their relatively large size. (After Waldeyer).—330, *B*. Two young follicles isolated; in 1, the cells of the follicle form but a single layer around the young primitive egg; in 2, they form a double layer; in 2, they begin to form the primary chorion (*a*), or the *zona pellucida* (vol. i. p. 135).—330, *C*. A mature human Graafian follicle: *a*, the mature egg; *b*, the surrounding follicle-cells; *c*, the epithelial cells of the follicle; *d*, the fibrous membrane of the follicle; *e*, its outer surface.

The entire natural history of the human sexual organs is one of the branches of Anthropology which affords the strongest proofs of the origin of the human race from the animal kingdom. Each man, on knowing the pertinent facts, and without prejudice, judging these comparatively, can but be convinced that he is descended from lower Vertebrates. The general, and the more minute structure, the activity and the individual evolution of the sexual organs, is exactly the same in Man as in Apes. This is as true of the male as of the female, of the internal as of the external genitalia. The differences in this matter between Man and the most man-like Apes are far less than the differences between the various forms of Apes. As, however, all Apes are undoubtedly from a common origin, this fact alone proves, with absolute certainty, the descent of Man from Apes.

TABLE XLIII.

Systematic Survey of the most Important Periods in the Phil of the Urinary and Sexual Organs of Man.[137]

XLIII. *A.* First main division: the sexual organs (G) and the uri organs (U) are distinct. (The sexual or genital system (G) and t excretory or urinary system act independently of each other.)

I. *First Period: Genitals and Kidneys of Gastræads.*

G. Single, scattered cells of the entoderm change into egg-cells; sing scattered cells of the exoderm into sperm-cells.

U. Special urinary organs are as yet wholly wanting. Secretion performed by the cells of the exoderm.

II. *Second Period: Genitals and Kidneys of Primitive Worms.*

G. The egg-cells of the entoderm gather into groups (ovary-plates); do the sperm-cells of the exoderm (testis-plates).

U. A pair of simple pouch-like skin-glands (products of the skin-sens layer) develop into extremely simple kidney-canals (excretory organs of Flat-worms, *Platelminthes*).

III. *Third Period: Genitals and Kidneys of Scolecida.*

G. After the differentiation of the four secondary germ-layers is c plete, the egg-cells pass from the skin-sensory layer into the skin-fib layer; the sperm-cells also pass from the intestinal-glandular layer into intestinal-fibrous layer.

U. After the formation of the cœlom is completed, the blind inner e of the two kidney-canals (or "primitive kidney ducts") open into the b cavity (*cœloma*).

IV. *Fourth Period: Genitals and Kidneys of Chordonia.*

G. The groups of egg-cells (ovarial plates) and the groups of sperm-c (testes-plates) meet at the boundary between the endocœlar (the visc intestinal-fibrous layer of the cœlom-epithelium) and the exocœlar (parietal skin-fibrous layer of the cœlom-epithelium), so as to form hermaphrodite glands.

U. The primitive kidney ducts differentiate into an excretory an glandular part.

V. *Fifth Period: Genitals and Kidneys of Acrania.*

G. The sexes become distinct. In the female, only the ovary is veloped; in the male, only the testes.

U. The primitive kidney ducts remain simple (atrophied in *Amphiox*

VI. *Sixth Period: Genitals and Kidneys of Cyclostoma.*

G. The sexual glands (numerous in *Acrania*) coalesce into a pair.

U. The primitive kidney ducts send out lateral branches which acquire scular coils (*glomeruli*) (the semi-pinnate primitive kidneys of *Bdello-ma*).

LIII. *B.* Second main division: the genital organs (G) and the urinary organs (U) become united. (The sexual system and the urinary system are united in the "urogenital system.")

VII. *Seventh Period: Urogenitals of Primitive Fishes (Selachii).*

The primary primitive kidney duct differentiates on each side, forming wo secondary canals; the Wolffian duct, which develops into the seed-duct, nd the Müllerian duct, which develops into the oviduct. Both genital ucts originally open behind the anus (*Proselachii*).

VIII. *Eighth Period: Urogenitals of Dipneusta.*

A cloaca is formed by the union of the urogenital opening and the cavity f the anus. The single urinary bladder grows out from the anterior wall of he rectum (*Lepidosiren*).

IX. *Ninth Period: Urogenitals of Amphibia.*

From the uppermost part of the primitive kidney which is in process of trophy, proceeds, in the male sex, the supplementary testis; in the female ex, the supplementary ovary. The Wolffian duct yet acts, in both sexes, as urinary canal, and, in the male, also as the seed-duct. The Müllerian uct acts in the female sex as oviduct; in the male it is a rudimentary rgan (Rathke's duct).

X. *Tenth Period: Urogenitals of Protamnia.*

The atrophied primitive kidney is replaced by the permanent secondary idney as the urinary organ. The urinary bladder grows out from the entral orifice of the embryo and forms the allantois. From the anterior all of the cloaca grows the sexual protuberance (*phallus*), which, in the ale, develops to the penis, in the female, to the clitoris.

XI. *Eleventh Period: Urogenitals of Monotremes.*

The lower end of the oviduct enlarges on each side to a muscular terus.

XII. *Twelfth Period: Urogenitals of Marsupialia.*

The cloaca is separated by a partition into an anterior urogenital opening *pertura urogenitalis*) and a posterior anal opening (*anus*). From the

lower part of the uterus the vagina-canal passes out on each side
ovaries and testes begin to move downward from their place of form

XIII. *Thirteenth Period: Urogenitals of Semi-apes.*

The lower parts of the Müllerian and the Wolffian ducts coales
a sexual cord. The coalescence of the two uteri at the lower par
rise to the *uterus bicornis*. A part of the allantois becomes the plac

XIV. *Fourteenth Period: Urogenitals of Apes.*

The two uteri coalesce throughout their entire length, forming a
pear-shaped uterus, as in Man.

TABLE XLIV.

ic Survey of the Homologies of the Sexual Organs in the two Sexes of Mammals.

LIV. *A.* Homologies of the Internal Sexual Organs.

non Rudiments of the nal Sexual Organs.	M. *Internal Male Parts.*	F. *Internal Female Parts.*
rm-gland (testes-plate embryo, product of the yer?)	1. Testis (*Testis*, or *Orchis*)	1. Rudimentary testis disappears,—remains in some Amphibia
erm-gland (ovary-plate, t of the intestinal)	2. (Rudimentary ovary, disappears,—remains in some Amphibia)	2. Ovary (*Ovarium*, or *Oophoron*)
duct (lateral primitive duct)	3. Seed-duct (*Spermaductus*)	3. Gartnerian duct (rudimentary canal)
an duct	4 *a.* Rathke's duct (rudimentary canal in Amphibia)	4 *a.* Oviduct (*Oviductus*, or *Tuba Fallopiæ*)
r Mülleri, central pri- kidney duct)	4 *b.* *Hydatis Morgagni*	4 *b.* *Hydatis Fallopiæ*
part of the Müllerian	4 *c.* *Uterus masculinus* (*Vesicula prostatica*)	4 *c.* Uterus, sheath (*vagina*)
part of the Müllerian	5. Supplementary testes (*Epididymis*)	5. Supplementary ovary (*Parovarium*)
of the primitive kidney *nephron, corpus Wolf-*	6. Hunterian guiding-cord (*Gubernaculum Hunteri*)	6. Round uterus-cord (*Ligamentum uteri rotundum*)
ament of the primitive *entum protonephroin-*)	7. Testis-mesentery (*Mesorchium*)	7. Ovary-mesentery (*Mesovarium*)
sentery *terium sexuale*)		

LIV. *B.* Homologies of the External Sexual Organs.

ion Rudiments of the al Sexual Organs.	M. *External Male Parts.*	F. *External Female Parts.*
protuberance *us*)	8. Penis	8. Clitoris
in *utium*)	9. Male fore-skin (*Præputium penis*)	9. Female fore-skin (*Præputium clitoridis*)
folds *genitales*)	10. Testes-sac (*Scrotum*)	10. *Labia pudendi majores*
between the two sexual	11. Seam of the testis-sac (*Raphe scroti*)	11. Female *Vulva*
edges (edges of the furrow)	12. Edges of the sexual furrow coalesce	12. *Labia pudendi minora*
tal canal *uregenitalis*)	13. Ureters (*Urethra*)	13. Antechamber of the vagina (*Vestibulum vaginæ*)
ar appendages of the tal canal	14. Cowper's glands	14. Bartholi's glands

CHAPTER XXVI.

RESULTS OF ANTHROPOGENY.

Review of the Germ-history as given.—Its Explanation by the Fund
Law of Biogeny.—Its Causal Relation to the History of the
Rudimentary Organs of Man.—Dysteleology, or the Doctrine
poselessness.—Inheritances from Apes.—Man's Place in the
System of the Animal Kingdom.—Man as a Vertebrate and a M
—Special Tribal Relation of Men and Apes.—Evidences regard
Ape Question.—The Catarhina and the Platyrhina.—The Divine
of Man.—Adam and Eve.—History of the Evolution of the
Important Mental Differences within a Single Class of Animal
Mammalian Mind and the Insect Mind.—Mind in the Ant and
Scale-louse (*Coccus*).—Mind in Man and in Ape.—The Organ of
Activity: the Central Nervous System.—The Ontogeny and
logeny of the Mind.—The Monistic and Dualistic Theories
Mind.—Heredity of the Mind.—Bearing of the Fundamental
Biogeny on Psychology.—Influence of Anthropogeny on the Vic
the Monistic Philosophy and the Defeat of the Dualistic.—Natu
Spirit.—Natural Science and Spiritual Science.—Conception
World reformed by Anthropogeny.

"The Theory of Descent is a general inductive law which result
absolute necessity from the comparative synthesis of all the phenom
organic nature, and especially from the threefold parallel of phylog
ontogenetic, and systematic evolution. The doctrine that man h
veloped from lower Vertebrates, and immediately from genuine A
a special deductive conclusion, which results with absolute necessity
the general inductive law of the Theory of Descent. This view of

ace in nature,' cannot, we believe, be made too prominent. If the Theory Descent is correct as a whole, then the theory that man has developed om lower Vertebrates is simply an unavoidable deductive conclusion from at general inductive law. Hence, all farther discoveries which may in ture enrich our knowledge of the phyletic development of man, can only confirmative of special points of that deduction, which rests on the oadest inductive basis."—*Generelle Morphologie* (1866).

AS we have now traversed the wonderful territory of he history of human development, and learned its most nportant parts, it seems appropriate that, at the close of our travels, we should look back on the road behind us, and, on the other hand, glance forward along the further path of knowledge into which our road will lead in future. We started from the simplest facts of the history of man's individual development; ontogenetic facts which can, at any moment, be shown and established by microscopic or anatomic research. The first and most important of these ontogenetic facts is, that every man, like every other animal, is at the commencement of his individual existence, a simple cell. This egg-cell exhibits precisely the same structure and mode of origin as that of any other Mammal. From this cell proceeds, by repeated division, a many-celled body, the mulberry-germ (*morula*); this changes into a cup-germ (*gastrula*), and this, again, into an intestinal germ-vesicle (*gastrocystis*). The two distinct cell-strata which compose its wall are the two primary germ-layers; the skin-layer (*exoderma*) and the intestinal layer (*entoderma*). This double-layered germ-form is the ontogenetic reproduction of that extremely important phylogenetic parent-form of all Intestinal Animals, to which we have given the name Gastræa.

As the human germ, like that of other Intestinal Animals,

passes through this gastrula-form, we are enabled to its phylogenetic origin back to the Gastræa. By tracı germ-history of the two-layered germ still farther, we that, by fission, four secondary layers are produced the two original germ-layers. These have exactly the constitution and genetic significance in Man as in all Vertebrates. From the skin-sensory layer develop outer skin (*epidermis*) and the central nervous systen probably, the kidney system. The skin-fibrous layer the leather-skin (*corium*) and the organs of motio skeleton and muscle systems). From the intestinal-l layer originates the vascular system and the fleshy the intestine. The intestinal-glandular layer, finally, only the epithelium, or the inner cellular layer intestinal-mucous membrane and of the intestinal gla

The manner in which these various organic s develop from the four secondary germ-layers, is, fro very first, exactly the same in Man as in all other brates. The germ-history of each separate organ a proof that the human embryo takes exactly the same direction in its differentiation and formation, which, in Man, occurs only in the other Vertebrates. With great animal tribe we then traced, step by step, and after stage, the farther development which takes place entire body as well as in all its several parts. This development takes place in the human embryo in th peculiar to Mammals. Finally, we saw, that even this class the various stages of phylogenetic develo which determine the natural classification of Ma correspond throughout to the various stages of onto formation through which the human embryo passes

further course of its development. We were thus enabled to determine the place of Man more definitely in the system of this class, and accordingly to establish the nature of his relation to the various mammalian orders.

The course of reasoning which we adopted in explaining these ontogenetic facts, was simply the logical carrying out of the fundamental law of Biogeny. In so doing we have constantly tried to carry out the significant distinction between palingenetic and kenogenetic phenomena. Palingenesis, or "the history of inheritance," alone enabled us to draw direct conclusions from observed germ-forms as to the tribal forms transmitted by heredity. On the other hand, these conclusions were more or less endangered, wherever Kenogenesis, or "vitiated evolution," was introduced by new adaptations. The whole understanding of the history of individual evolution depends on the recognition of this most important relation. We stand here on the border-line which sharply divides the new from the old method of scientific investigation, the new from the old conception of the world. All the results of recent morphological research drive us with irresistible force to the recognition of this fundamental principle of Biogeny, and of its far-reaching consequences. These are, it is true, irreconcilable with the customary mythological ideas of the world, and with the powerful prejudices engrafted into us in early youth by theosophic instruction; but, without this fundamental law of Biogeny, without the distinction between Palingenesis and Kenogenesis, and without the Theory of Descent, upon which these are based, we are entirely unable to understand the facts of organic development; without these, we cannot afford the faintest explanation of any part of this great and

wonderful world of phenomena. But, if we recognize the causal relation between the development of the germ and that of the tribe, if we recognize the true causal connection of Ontogeny and Phylogeny, which is expressed in that law, then the wonderful phenomena of Ontogeny explain themselves most simply; then the facts of germ-development appear but the necessary mechanical effects of the development of the tribe, conditioned by the laws of Heredity and Adaptation. The inter-operation of these laws among the everywhere-active influences of the struggle for existence, —or, as we may simply say with Darwin, Natural Selection, —is amply sufficient to explain to us the entire process of germ-history by the history of the tribe. Darwin's chief merit lies in the fact, that by the discovery of the interaction of the phenomena of Heredity and Adaptation, he prepared the way for a correct, logical understanding of the history of Evolution.

Among the numerous and important evidences that we have found for the truth of this view of our development history, I will only call attention here once more to the peculiarly valuable records of creation afforded by Dysteleology, or the doctrine of purposelessness, the science dealing with rudimentary organs. It is impossible to emphasize too often and too strongly the high morphological importance of those remarkable parts of the body, which are, physiologically, completely worthless and useless. In every system of organs we find, in Man and in all higher Vertebrates, some of these worthless primæval heirlooms, which have been inherited from our lower vertebrate ancestors. Thus, first, we find on the outer surface of the body a scanty rudimentary covering of hair, which is thicker only on the

ead, in the armpits, and on some other parts of the body. The hort hairs on the greater part of the surface of our bodies are ntirely useless, are without any physiological significance; hey are the last scanty remains of the much more fully eveloped hairy covering of our Ape ancestors (p. 208). The ense-organs exhibit a series of the most remarkable rudimen-ary parts. As we have seen, the whole external shell of the ear, with its cartilages, muscles, and membranes, is, in Man, a useless appendage, destitute of the physiological importance that was formerly, erroneously, attributed to it. It is the atrophied remnant of the pointed, freely-moving, and much more highly developed mammalian ear, the muscles of which we retain, although we can no longer use them (p. 271). Again, we found, at the inner corner of the human eye, the remarkable little crescent-shaped fold, which is of no use to us, and is of interest only as being the last vestige of the nictitating membrane; of that third inner eyelid which is still of great physiological importance in Sharks and many Amnion Animals (p. 259). Numerous and interesting dysteleological proofs are also afforded by the apparatus of motion, both by the bony and the muscular systems. I will only cite the free, projecting tail of the human embryo, and the rudimentary caudal vertebræ developed in the latter, together with the pertinent muscles; this whole organ is entirely useless to Man, but is of great interest as the atrophied remnant of the long tail of our earlier Ape ancestors, which was composed of numerous vertebræ and muscles (p. 283). From these same ancestors we have also inherited various bone-processes and muscles, which were of great use to them in their climbing life among the trees, but with us have fallen out of use. At various points under the

skin we also have entirely unused skin-muscles; vestig
the largely developed skin-muscles of our lower n
malian ancestors. It was the function of this "pann
carnosus" to contract and wrinkle the skin, as we ma
any day done by horses to drive away flies. We
possess an active remnant of this great skin-muscle in
muscle of the forehead, by means of which we wrinkl
forehead and draw up the eyebrows; but we are no lo
able to move at will another considerable remnant of it
great skin-muscle of the neck (*platysma myoides*).

As in these animal organ-systems of our body, so al
the vegetative apparatus, we meet with many rudime
organs, most of which we have incidentally noticed. I
only cite the remarkable thyroid gland (*thyreoidea*)
rudiment of the crop and the remnant of the ciliated g
(hypobranchial groove) present in Chordonia, Ascidia
Arcrania, on the lower part of the gill-body (pp. 336,
also the vermiform process of the blind-intestine (*ca*
(p. 344). In the vascular system we find many u
ducts, the vestiges of disused vessels which were for
active blood-channels; such, for instance, are the "*d*
Botalli," between the lung-artery and the aorta,
the "*ductus venosus Arantii*," between the *vena*
and *vena cava*, and many others. The numerous
mentary organs of the urinary and sexual systems (p
are especially interesting. Most of these are develop
one sex and rudimentary in the other. Thus, in the
the seed-ducts form from the Wolffian ducts, of whic
only traces remaining in the female are the Gartn
canals. On the other hand, from the Müllerian ducts i
female are developed the oviducts and the uterus; wh

the male, only the lower extremities of these ducts remain, forming the useless male uterus (*vesicula prostatica*). In the nipples and mammary glands, the male possesses other rudimentary organs which, as a rule, are functional only in the female (p. 204).

A closer anatomical examination of the human body would bring to our notice a number of other rudimentary organs, all of which can be explained only by the Theory of Descent. They are among the most important evidences for the truth of the mechanical theory of nature, and among the most overwhelming proofs against the prevailing teleological ideas of creation. If, in accordance with this latter view, Man and every other organism had been designed for his life-purpose from the beginning, and had been called into existence by an act of creation, the existence of these rudimentary organs would be an incomprehensible enigma; it would be impossible to understand why the Creator should have laid this useless burden on his creatures in their life-journey, so arduous at the best. On the other hand, by means of the Theory of Descent we can explain their existence in the most simple way, and say: The rudimentary organs are parts of the body, which, in the course of centuries, have gradually fallen out of use; organs which performed definite functions in our animal ancestors, but which, in us, have lost their physiological importance. They have become useless in consequence of our adaptation to new circumstances, but yet are transmitted from generation to generation by heredity, and have only slowly atrophied.

Like these rudimentary organs, so also all the other organs of our body have been transmitted to us from Mammals, and, immediately, from our Ape ancestors. The

human body includes no single organ which is not i
herited from Apes; but, by means of our fundamental l
of Biogeny, we can trace the origin of our several sys
of organs yet further down to various lower ancest
grades. Thus, for instance, we can say that we h
inherited the earliest organs of our body, the outer-sk
(*epidermis*) and the intestinal canal, from the Gastrea
the nervous and muscular systems from the lower Wo
(*Archelminthes*), the vascular system, body-cavity (*cœlom*)
and blood from Soft Worms (*Scolecida*), the notochord a
the gill-intestine from Chorda Animals, the differentiated
organs of sense from the Cyclostoma, the limbs and the
Müllerian ducts from Primitive Fishes (*Selachii*), and the e
ternal reproductive organs from Primitive Mammals (*Pr*
mammalia). When we stated the "law of the ontogenet
connection of systematically allied forms," and determin
the relative age of the organs, we saw how we could dr
such phylogenetic conclusions as these from the ontogene
succession of the organ-systems (vol. i. p. 390; ii. 357).

By the help of this important law and of Comparati
Anatomy, we were also enabled to determine definit
"man's place in nature," or, as we may say, to assign
man his position in the system of the animal kingdom.
is now usual, in the more recent zoological systems,
distribute the whole animal kingdom into the seven trib
or *phyla*, which are again sub-divided, in round numb
into about forty classes; and these classes into ab
two hundred orders. According to his whole organizati
Man is undoubtedly, primarily, a member of but a sin
tribe, that of Vertebrates; secondly, he is a member of b
a single class, that of Mammals; and, thirdly, a meml

but a single order, that of the Apes. All the characteristic peculiarities, distinguishing Vertebrates from the other tribes, distinguishing Mammals from the other forty classes, and distinguishing Apes from the remaining two hundred orders of the animal kingdom, are also present in Man. Turn and twist as we may, we cannot escape this anatomical and systematic fact. Quite recently this very fact has led to the liveliest discussion, and has occasioned, especially, many disputes about the specific anatomical relationship of Man to Apes. The most astounding views on this "ape question," or "pithecoid theory," have been uttered. It will therefore be well to examine it closely once more at this point, and to separate the essential from the non-essential in it.

We will start from the undisputed fact, that Man, at all events,—whether his special blood-relationship to Apes is acknowledged or denied,—is a genuine Mammal, is a Placental Mammal. This fundamental truth can be so easily proved at any moment by investigations in Comparative Anatomy, that it has been unanimously acknowledged since the separation of the Placental from the lower Mammals (Pouched Animals, or *Marsupialia*, and Beaked Animals, or *Ornithostoma*). But, from this, every logical adherent of the doctrine of development at once draws the conclusion, that man is descended from one and the same common parent-form, together with all other Placental Animals, from the progenitor of the *Placentalia*, just as, further, we must *necessarily* suppose a common mammalian ancestral form of all the various Mammals (*Placentalia*), Pouched Animals, and Cloacal Animals (*Monotremata*); but by this the great, all-agitating main question of man's place in nature is

conclusively settled, whether we ascribe to Man a near a more remote relationship to Apes. No matter wh Man is, in a phylogenetic sense, a member of the Ape (or, if it is preferred, of the Primate order) or not, any case, his direct blood-relationship to all other Ma and especially to the Placental Mammals, is established. may be that the inter-relations of the various Ma are quite different from those now hypothetically assu but, in any case, the common descent of Man and other Mammals from a common parent-form is indi putable. This primæval, long since extinct parent-fo which probably developed during the Triassic Period, wa the monotreme ancestral form of all Mammals.

If this fundamental and extremely significant princip is borne in mind, the "ape question" will appear to u in a wholly different light from that in which it is usually presented. A little reflection will bring conviction tha this question has not the importance that has of late bee attributed to it; for the origin of the human race fro a series of various mammalian ancestors, and the historic development of the latter from an earlier series of low vertebrate ancestors, remains indubitably established, matter whether the genuine "Apes" are regarded as th nearest animal ancestors of the human race or not. Bu it having become habitual to lay the principal weight the entire question of the origin of man on this ve "descent from Apes," I find myself compelled to retu once more to it here, and to recall those facts in Co parative Anatomy and Ontogeny, which conclusively sett this "ape question."

The shortest way to the goal is the one taken b

xley in his celebrated work, which we have so often ted, on the "Evidences as to Man's Place in Nature,"— way afforded by Comparative Anatomy and Ontogeny. have to compare objectively all the several organs of n with the same organs in the higher Apes, and then to ertain whether the differences between the former and latter are greater than the corresponding differences ween the higher and lower Apes. The indubitable and isputable result of this comparative anatomical investi- ion which was conducted with the greatest candour and uracy, was the important law, which, in honour of its coverer, we have named *Huxley's Law;* namely, that the ysical differences between the organization of Man and at of the most highly developed Apes known to us, are ch smaller than the corresponding differences between e higher and lower Apes. We might even define this law t more exactly by excluding entirely the Platyrhina or merican Apes as being more remote relatives, and limiting ar comparison to the narrower circle of relatives, the atarhina, or Apes of the Old World. Even within this mall group of Mammals, we found the differences of struc- ure between the higher and lower Narrow-nosed Apes, for xample between the Gorilla and the Baboon, much greater han the differences between these Man-like Apes and Man. Vhen, in addition, we now turn to Ontogeny, and when we ind there, according to our "law of the ontogenetic con- ection of systematically related forms, that the embryos of Man and of the Man-like Apes, are identical for a longer eriod than the embryos of the highest and of the lowest pes, we are certainly obliged to bring ourselves, whether ith a good or a bad grace, to acknowledge our origin from

the Ape order. From the facts exhibited by Comp
Anatomy, we can undoubtedly form in imaginati
approximate image of the structure of our ancestors
the older Tertiary Period; we may fill out the details
will, yet this image will be a genuine Ape, and
Catarhine. For Man has all the physical character
tinguishing the Catyrhina from the Platyrhina. A
ingly, in the mammalian pedigree, we must deriv
human race directly from the Catarhine group, and
the origin of Man to the Old World. For the entire
of the Catarhine Apes has, as yet, been confined to th
World, just as the group of the Platyrhine Apes has
limited to the New. Only the earliest root-form, that
which both groups sprang, was common to them; pr
it originated from the Semi-apes of the Old World.

Therefore, although it is thus indubitably establis
the result of our objective scientific inquiry, that the
race is directly descended from the Apes of the Old
yet we will once more state emphatically that this
cant fact is not of as great importance to the main q
of the origin of Man, as is generally supposed. Fo
if we entirely ignore the fact or thrust it aside, t
not affect all that the zoological facts of Comp
Anatomy and the history of development have ta
concerning the placental character of Man. These
prove the common descent of Man and the other Ma
It is evident also, that the main question cannot be
least evaded or set aside by the statement: "Man is,
a Mammal; but he branched off from the others q
the root of the class, and has no nearer relationsh
any other extant Mammal." At all events, the relat

idently more or less close if we comparatively examine
elation of the Mammalian class to the remaining forty
es of the animal kingdom. All Mammals, including
, are, at least, of common origin, and it is equally
in that their common parent-forms gradually developed
a long series of lower Vertebrates.

Feeling, evidently, rather than understanding, induces
people to combat the theory of their "descent from
s." It is simply because the organism of the Ape appears
ricature of Man, a distorted likeness of ourselves in a
very attractive form, because the customary æsthetic
s and self-glorification of Man are touched by this in so
itive a point, that most men shrink from recognizing
descent from Apes. It seems much pleasanter to be
ended from a more highly developed, divine being,
hence, as is well known, human vanity has, from the
est times, flattered itself by assuming the original
ent of the race from gods or demi-gods. The church,
that sophistical distortion of ideas of which she is
great an adept, has managed to extol this ridiculous
e as Christian humility; and those people who
t with haughty horror every suggestion of descent
lower animals, and consider themselves children of
, those very people are exceedingly fond of boasting
it their childlike humility of spirit. In most of the
ions delivered against the progress of the doctrine
volution, human vanity and conceit play throughout
rominent part; and, although we have inherited this
acteristic weakness from Apes, yet we must confess to
ng developed it to a degree of perfection which
pletely overthrows the unprejudiced judgment of the

"sound understanding of man." We ridicule the el
follies occasioned by the pride of ancestry amon
nobility, from the splendid Middle Ages down to ou
time, and yet no small portion of this groundless
of nobility lurks in a great majority of men. Just as
people prefer to trace their pedigree from a decayed
or, if possible, from a celebrated prince, rather than
an unknown, humble peasant, so they prefer seeing th
genitor of the human race in an Adam degraded by th
rather than in an Ape capable of higher developme
progress. It is a matter of taste, and such genea
preferences do not, therefore, admit of discussion.
must confess that, personally, I am as proud of my p
grandfather, who was simply a Silesian peasant, as
maternal grandfather, who raised himself from the p
of a Rhenish lawyer to the highest posts in the
of state. And it is also much more to my individu
to be the more highly developed descendant of a pr
Ape ancestor, who, in the struggle for existence, l
veloped progressively from lower Mammals, as the
still lower Vertebrates, than the degraded descen
an Adam, god-like, but debased by the Fall, who was
from a clod of earth, and of an Eve, created from
Adam. As regards this celebrated "rib," I must h
pressly add as a supplement to the history of the d
ment of the skeleton, that the number of ribs is the s
man and in woman. In the latter as well as in the
the ribs originate from the skin-fibrous layer, and are t
garded phylogenetically as lower or ventral vertebræ (p

Now I certainly hear some one say: "That may
right and correct as far as the human body is concerne

the facts presented, it is certainly no longer to be ted that this has actually developed gradually, step by from the long ancestral series of Vertebrates; but it is otherwise with the 'spirit of man,' with the human l, which cannot possibly have developed in a similar from the mind of lower Vertebrates." Let us see if the vn facts of Comparative Anatomy, Physiology, and ution can meet this grave objection. We shall best firm ground from which to start in this matter by paratively examining the minds of the different Verte- es. Side by side within the various classes, orders, ra, and species of Vertebrates, we find so great a variety ertebral intellects, that, at first sight, one can scarcely it possible that they can all be derived from the mind common "Primitive Vertebrate." First, there is the Lancelet, which has no brain at all, but only a simple allary tube, the entire mental capacity remaining at very lowest grade occurring among Vertebrates. The ostomi, also, standing just above, exhibit a hardly er mental life, though they have a brain. Passing on to es, we find their intelligence, as is well known, also very low point. Not until from these we ascend to the hibia, is any essential progress in mental development rvable. This is much greater in Mammals, although, here, in the Beaked Animals (*Ornithostoma*), and the higher class, the stupid Pouched Animals (*Marsupials*), entire mental activity is still of a very low order; but e pass on from these to Placental Animals, within this iform group we find such numerous and important in differentiation and improvement, that the mental rences between the most stupid Placental Animals (for

instance, Sloths and Armadillos) and the most intel
animals of the same group (for instance, Dogs and
seem much more considerable than the intellectu
ferences between those lowest Placentals and the P
Animals, or even the lower Vertebrates. Those diffe
are, at any rate, much more considerable than th
ferences in the intellectual life of dogs, apes, and men.
yet all these animals are allied members of a single c

This fact is shown to a yet more surprising de
the Comparative Psychology of another class of a
which is specially interesting for many reasons,
Insects. It is well known that many Insects ex
mental capacity approximately as highly develope
possessed by Man only of the vertebrate group. It is n
to speak of the celebrated organized communities an
of Bees and Ants; every one knows that very rem
social arrangements occur among these, such as occu
equal degree of development only in the higher r
men, and nowhere else in the animal kingdom. I w
allude to the civil organization and government
Monarchical bees and Republican ants, to their d
into various orders: the queen, the drone nobilit
workers, the nurses, soldiers, and so on. Among th
remarkable phenomena in this extremely interesting
life, is certainly the cattle-keeping of certain Ants,
tend plant-lice for the sake of their milk and re
collect their honey-juice. Even more remarkable
slave-holding of the large red Ants, which steal the
of the small black species and rear them to slave-
It has long been known that all these civil and
arrangements of the Ants were originated by the syst

-operation of numerous citizens, understanding each other. umerous observations have placed the astoundingly high tellectual development of these little Articulated Animals yond all doubt. With this let us compare, as Darwin as done, the intellectual capacity of many lower, and, specially, of many parasitic, Insects. There, for example, re the Scale Insects (*Coccus*) which, when mature, consist f an entirely immovable shield-shaped body attached to he leaves of plants. Their feet are atrophied. Their nouths are embedded into the tissue of the plant, the uices of which they suck. The whole mental activity of his motionless female parasite consists in the enjoyment it lerives from sucking these juices and from sexual intercourse with the unattached male. The same is true of the maggot-like female of the Twisted-wings (*Strepsiptera*), which spends its whole life, wingless and footless, as a motionless parasite in the body of the wasp. There can be no suspicion of any higher mental activity there. If these brutish parasites are compared with the mentally active and sensible ants, it will certainly be admitted, that the psychical differences between the two are much greater than those between the highest and lowest Mammals, between Beaked Animals (*Ornithostoma*), Pouched Animals (*Marsupialia*), and Armadillos on the one hand, and Dogs, Apes, and Men on the other. And yet all those insects belong, without question, to the single class of Arthropoda, just as all these Mammals undoubtedly belong to the single class of Vertebrates; and just as every logical adherent of the doctrine of evolution must assume a common parent-form for all those Insects, so also he must necessarily assert a common descent for all these Mammals.

Turning now from observing the comparative mental capacity of the various animals to the question as to the organs of these functions, we receive the answer, that in the higher animals they are invariably connected with certain groups of cells, those cells which compose the central nervous system. All naturalists, without exception, agree that the central nervous system is the organ of the mental life of animals, and this assertion is at any time capable of experimental proof. If the central nervous system is wholly or partially destroyed, the "mind," or the psychical activity of the animal, is wholly or partially annihilated at the same time. We must, therefore, next inquire what is the character of the mental organ in man. The undeniable answer to this question has already been given. Man's mental organ is, in its whole structure and origin, the same as that of all other Vertebrates. It originates as a simple medullary tube from the outer skin of the embryo, from the skin-sensory layer, or the first of the secondary germ-layers. In the course of its gradual development it passes through the same stages of progression in the human embryo as in that of all other Vertebrates, and as these latter have undoubtedly a common origin, so must also the brain and spinal cord be of the same origin in all.

Physiological observation and experiment teaches, moreover, that the relation of the "mind" to its organ, the brain and spinal marrow, is exactly the same in Man as in all other Mammals. The former can in no case act without the latter; the one is connected with the other, as is muscular movement with muscle. Therefore, the mind can develop only in connection with its organ. Adherents of the Theory of Descent, who concede the causal connection

n Ontogeny and Phylogeny, are now compelled to ze the following propositions: The mind, or "psyche," has developed together with, and as the function of dullary tube, and just as even now the brain and narrow develop in each human individual from the medullary tube, so the human "mind," or the mental y of the entire human race, has developed gradually, step, from the mind of lower Vertebrates. Just as ow in every individual of the human race the ful and complex structure of the brain develops y step from exactly the same rudiment, from the ve simple brain-bladders, as in all other Skulled s (*Craniota*), so the human mind has gradually ed in the course of millions of years from the mind r Skulled Animals; and as now the brain of every embryo differentiates according to the special type Ape-brain, so also the human psyche has historically tiated from the Ape-mind.

s monistic idea will, of course, be indignantly re- by most people, who accept the contrary dualistic hich denies the inseparable connection of the brain mind, and regards "body and mind" as entirely and distinct; but how shall we reconcile this ly accepted view with the facts taught by the of evolution? The dualistic view is, at least, as ilably opposed to Ontogeny as to Phylogeny. If e with the majority of men, that the mind is a self-, independent being, which has originally nothing ith the body, but only dwells in it for a time, and gives expression to its emotions through the brain, piano-player through his instrument, then we must

suppose a period in the human germ-history, at which the mind enters the body, enters the brain; and we must also suppose a moment at death, at which it leaves the body; and further, as every man inherits certain individual mental qualities from each parent, we must suppose that portions of the mind of each were transferred to the germ at the time of its procreation. A little piece of the father's mind accompanied the sperm-cell, a little piece of the mother's mind remained with the egg-cell. This dualistic view entirely fails to explain the phenomena of evolution. We all know that the new-born child has no consciousness, no knowledge of itself and of the objective world. Whoever has children of his own, and follows their mental development candidly, cannot possibly deny that processes of biological evolution are at work there. Just as all other functions of the body develop in connection with their organs, so does the mind develop in connection with the brain. And this gradual development of the child's mind is such a wonderful and beautiful phenomenon, that every mother and every father with eyes to see takes unwearied delight in observing it. The text-books of Psychology alone are ignorant of any such development, and we are almost forced to the conclusion that their authors themselves never had any children. The human mind, as it is represented in the great majority of psychological works, is only the one-sided mind of a learned philosopher, who, indeed, knows many books, but nothing of the process of evolution, and does not suspect that even his own mind has developed.

These same dualistic philosophers must, of course, if they are consistent, also assume that there was a moment

the Phylogeny of the human mind at which this mind first entered the vertebrate body of man. Accordingly, at the time when the human body developed from the body of the Anthropoid Ape (thus, probably, in the latter part of the Tertiary Period), a specific human mind-element—or, as it is usually expressed, a "divine spark"—must have suddenly entered or been breathed into the brain of the Anthropoid Ape, and there have associated itself with the already existing Ape-mind. I need not point out the theoretic difficulties involved in this conception. I will only remark that even this "divine spark," by which the mind of Man is said to be distinguished from that of all other animals, must itself be a thing capable of evolution, and has actually developed progressively in the course of human history. This "divine spark" is usually understood to be "reason," and is ascribed to man as a mental function distinguishing him from all "irrational animals." Comparative Psychology, however, teaches that this frontier-post between man and beast is altogether untenable.[198] We must either take the idea of reason in its broader sense, in which case it belongs to the higher Mammals (the Ape, Dog, Elephant, Horse), as much as to the majority of men; or we must conceive it in its narrower sense, and then it is lacking in the majority of men, as well as in most animals. On the whole, that which Goethe's Mephistopheles said of his time, is true of Man's reason to-day:

> "He might have kept himself more right
> Hadst Thou ne'er shewn to him a glimpse of heaven's light.
> He calls it Reason, but Thou seest
> Its use but makes him beastlier than the beast."

If, therefore, we must abandon this generally preferred.

and, in many respects, very pleasant dualistic theory of t
mind, as being wholly untenable, because irreconcil
with genetic facts, then the opposite monistic view al
remains to us, according to which the human mind, l
that of any other animal, is a function of the central ner
system, with which it has developed in inseparable c
nection. Ontogenetically, we see this in every ch
phylogenetically, we must assert it in accordance with
fundamental law of Biogeny. In every human em
the medullary tube develops from the skin-sensory l
and from the anterior part of that tube the five b
bladders of Skulled Animals (*Craniota*), and from t
the mammalian brain (at first with the characteristi
the lower, then with those of the higher Mamm
Just as this entire ontogenetic process is but a short r
duction, occasioned by Heredity, of the same process i
Phylogeny of Vertebrates, so also the wonderful m
activity of the human race has gradually developed,
by step, in the course of many thousands of years, from
less perfect mental activity of the lower Vertebrates.
the evolution of the mind in each child is only a
reproduction of that long phylogenetic process.

The extraordinary and important bearing of An
pogeny on Philosophy, in the light of the fundamental
ciple of Biogeny, now becomes apparent. The specul
philosophers who will take possession of the facts of
togeny and explain them phylogenetically (according to
law), will introduce a greater advance in the histor
Philosophy than has been made by the greatest thinke
all previous centuries. Undoubtedly every clear and lo
thinker must draw from the facts of Comparative Anat

nd Ontogeny which have been brought forward, a mass of suggestive thoughts and reflections which cannot fail of their effect on the further development of the philosophical study of the universe. Neither can it be doubted that these facts, if properly weighed, and judged without prejudice, will lead to the decisive victory of that philosophical tendency, which we distinguish, briefly, as monistic or mechanical, in distinction from the dualistic or teleological, on which most philosophical systems of ancient, mediæval, and modern times are based. This mechanical, or monistic philosophy, asserts that everywhere the phenomena of human life, as well as those of external nature, are under the control of fixed and unalterable laws, that there is everywhere a necessary causal connection between phenomena, and that, accordingly, the whole knowable universe forms one undivided whole, a "*monon*." It further asserts, that all phenomena are produced by mechanical causes (*causæ efficientes*), not by pre-arranged, purposive causes (*causæ finales*). Hence there is no such thing as "free-will" in the usual sense. On the contrary, in the light of this monistic conception of nature, even those phenomena which we have been accustomed to regard as most free and independent, the expressions of the human will, appear as subject to fixed laws as any other natural phenomenon. Indeed, each unprejudiced and searching test applied to the action of our "free-will" shows that the latter is never really free, but is always determined by previous causal conditions, which are eventually referable either to Heredity or to Adaptation. Accordingly, we cannot assent to the popular distinction between nature and spirit. Spirit exists everywhere in nature, and we know of no spirit out-

side of nature. Hence, also, the usual distinction b natural science and mental science is entirely unt Every real science is at the same time both a natural mental science. Man is not above nature, but in nat

The opponents of the doctrine of evolution are ve of branding the monistic philosophy grounded upo "materialism," by confusing *philosophical* materialis the wholly different and censurable *moral* mate Strictly, however, our "monism" might, as accuratel inaccurately, be called spiritualism as materialism real materialistic philosophy asserts, that the vital mena of motion, like all other phenomena of moti effects or products of matter. The other, opposite e spiritualistic philosophy, asserts, on the contrar matter is the product of motive force, and that all n forms are produced by free forces entirely indepen the matter itself. Thus, according to the mate conception of the universe, matter, or substance, p motion, or active force. According to the spiritualis ception of the universe, on the contrary, active f motion precedes matter. Both views are dualistic, hold them both to be equally false. A contrast views is presented in the *monistic* philosophy, which little believe in force without matter, as in matter force. It is only necessary to reflect on this for from a strictly scientific standpoint, to find that o examination it is impossible clearly to represent without the other. As Goethe says, "Matter car exist and act without spirit; neither can spirit matter."[12]

The "spirit" and "mind" of man are but forces

re inseparably connected with the material substance of ur bodies. Just as the motive force of our flesh is involved n the muscular form-element, so is the thinking force of ur spirit involved in the form-element of the brain. Our piritual forces are as much functions of this part of the ody, as every force is a function of a material body. We know of no matter which does not possess force, and, conversely, of no forces that are not connected with matter. When the forces manifest themselves in the phenomena of motion, they are called active forces; if, on the other hand, the forces are in a state of rest, or of equilibrium, they are called latent forces.[199] This is as true of inorganic natural substances as of organic. The magnet attracting iron-filings, powder exploding, steam driving the locomotive, are active inorganic substances; they work by active force just as does the sensitive mimosa, when it folds its leaves at a touch,—as does the Amphioxus, when it buries itself in the sand,—as does man, when he thinks. Only in these latter cases the combination of the different forces, appearing as phenomena of motion, are much more complex and much less easily recognized than in the former cases.

Anthropogeny has led us to the conclusion that even in the entire history of the evolution of man, in the history of the germ, as well as in that of the tribe, no other active forces have been at work, than in the rest of organic and inorganic nature. All the forces at work there can be reduced at last to *growth*—to that fundamental function of evolution by which the forms of inorganic, as well as of organic bodies, originate. Growth, again, itself rests on the attraction and repulsion of like and unlike particles.[194] It has given rise to Man and to Ape, to Palm and Alga, to

crystal and water. Hence the evolution of man has taken place according to the same "eternal, immutable law," as has the evolution of any other natural body.

It is true that the prejudices that stand in the way of the general recognition of this "Natural Anthropogeny" are even yet intensely powerful; otherwise the ancient strife between the various philosophical systems would already have been decided in favour of "Monism." But it can be foreseen with certainty that a more general acquaintance with genetic facts, will gradually destroy those prejudices and bring about the victory of the natural idea of "Man's Place in Nature." The fear is often expressed in opposition to this view that it will cause a retrogression in the intellectual and moral development of man; but, on the contrary, I cannot withhold my conviction, that the very reverse will be true, that by it the progressive development of the human spirit will be advanced in an unusual degree. At all events, I hope and trust that I have, in these chapters, afforded convincing proof that the only way to attain a true scientific knowledge of the human organism, is by employing the method which we must acknowledge to be alone correct and successful in the study of organic nature,—by following the course of the History of Evolution.[200]

NOTES.

REMARKS AND REFERENCES TO LITERATURE.

1 (vol. i. p. 2). Anthropogeny (Greek) = History of the Evolution of Man; from Anthropos (ἄνθρωπος) = man, and genea (γενεά) = Evolution history. There is no especial Greek word for "the history of evolution;" in its place is used either γενεά (= descent), or γονέια (= generation). If goneia is preferred to genea, the word must be written Anthropogony. The word "*Anthropogony*," used first by Josephus, means, however, only "the generation of man." Genesis (γένεσις) means "origination, or evolution;" therefore *Anthropogenesis* = "the evolution of man."

2 (i. 3). Embryo (Greek) = germ (ἔμβρυον). Really τὸ ἐντὸς τῆς γαστρὸς βρύον (Eust.), *i.e.* the unborn germ in the mother's body (Latin fœtus, or, better, fetus). In accordance with this original sense, the term embryo should only be applied to those young organisms which are still enclosed in the egg-coverings. (Cf. "Generelle Morphologie," vol. ii. p. 20.) Inaccurately, however, various free-moving young forms of low animals (larvæ) are often spoken of as embryos. Embryonic life ends at birth.

3 (i. 5). Embryology (Greek) = Germ-science, from embryon (ἔμβρυον) = germ, and logos (λόγος) = science. Even now the whole history of the evolution of the individual is erroneously called "embryology." For corresponding with the term "embryo" (see note 2), by "embryology," or "embryogony," should only be understood "the history of the evolution of the

individual within the egg-coverings." As soon as the orga
has left there, it is no longer a real "embryo." The later cha
of this form the subject of the science of Metamorphoses,
Metamorphology.

4 (i. 5). Ontogeny (Greek) = "germ-history," or "
history of the evolution of the individual;" from ὄντα = in
viduals, and genea (γενεά) = history of evolution. (Cf. note 1
Ontogeny, as the "history of the evolution of the individual
embraces both Embryology and Metamorphology (note 3).—
"Generelle Morphologie," vol. ii. p. 30.

5 (i. 5). Phylogeny (Greek) = tribal history, or "the p
læontological history of evolution;" from phylon (φῦλον) = trib
and genea (γενεά) = history of evolution. The phylon includ
all organisms connected by blood, which are descended from
common typical parent-form. Phylogeny includes Palæontolo
and Genealogy.—"Generelle Morphologie," vol. ii. p. 305.

6 (i. 6). Biogeny (Greek) = the history of the evolution
organisms or of living natural bodies in the widest se
(Genea tu biu.) βίος = life.

7 (i. 6). The fundamental law of Biogeny. Cf. my "Gen
History of the Evolution of Organisms" ("Generelle Morpholo
1866, vol. ii.), p. 300 (Essays on the causal connection of bioge
and phyletic evolution); also the "Monograph of C
Sponges" ("Monographie der Kalkschwämme," 1872, vol. i. 4
also my "Natural History of Creation."

8 (i. 10). Palingenesis (Greek) = original evolution, f
palingenesia (παλιγγενεσία) = new-birth, renewal of the fo
course of evolution. Therefore, Palingeny = inherited his
(from παλιν = reproduced, and γενεά = history of evolution).

9 (i. 10). Kenogenesis (Greek) = modified evolution, f
kenos (κενός) = strange, meaningless; and genea (γενεά) = his
of evolution. The modifications introduced into Palinge
by Kenogenesis are vitiations, strange, meaningless addition
the original, true course of evolution. Kenogeny = viti
history.

10 (i. 12). Latin definition of the fundamental law

ıy: "Ontogenesis summarium vel recapitulatio est phy-
seos, tanto integrius, quanto hereditate palingenesis con-
ur, tanto minus integrum, quanto adaptatione kenogenesis
ucitur." Cf. my "Aims and Methods of Recent History
olution" ("Ziele und Wege der Heutigen Entwickelungs-
chte," p. 77. Jena, 1876).

(i. 17). Mechanical and purposive causes. Mechanical
l philosophy assumes that throughout nature, in organic
as in inorganic processes, only non-purposive, mechanical,
arily-working causes exist (*causæ efficientes, mechanism,*
ity). On the other hand, vitalistic natural philosophy
that the latter are at work only in inorganic processes,
in certain other, purposive, special causes are at work,
ous or purposive causes, working for a definite end (*causæ*
Vitalism, Teleology). (Cf. "Generelle Morphologie,"
p. 94.)

(i. 17). Monism and Dualism. Unitary philosophy, or
m, is neither extremely materialistic nor extremely spirit-
c, but resembles rather a union and combination of these
d principles, in that it conceives all nature as one whole
owhere recognizes any but mechanical causes. Binary
phy, on the other hand, or Dualism, regards nature and
matter and force, inorganic and organic nature as distinct
dependent existences. (Cf. vol. ii. p. 456.)

(i. 20). Morphology and Physiology. Morphology (as
ience of forms) and Physiology (as the science of the
ons of organisms) are indeed connected, but co-ordinate
es, independent of each other. The two together constitute
y, or the "science of organisms." Each has its peculiar
ds and aids. (Cf. "Generelle Morphologie," vol. i. pp.
)

(i. 24). Morphogeny and Physiogeny. Biogeny, or the
ry of the evolution of organisms," up to the present time
een almost exclusively Morphogeny. Just as this first
the way to a true knowledge of organic forms, so will
geny afterwards make a true recognition of functions

possible, by discovering their historic evolution. Its promises to be most fruitful. Cf. "Aims and Methods Recent History of Evolution" ("Ziele und Wege der He Entwickelungsgeschichte," pp. 92–98. Jena, 1876).

15 (i. 27). Aristotle. Five books on the generatio evolution of animals (περὶ ζῴων γενέσεως).

16 (i. 28). Parthenogenesis. On "virginal genera or the "immaculate conception" of Invertebrates, especia Articulated Animals (*Crustacea*, *Insecta*, etc.), see Si "Remarks on Parthenogenesis among Arthropoda" ("Be zur Parthenogenesis der Arthropoden." Leipzig, 1871). Seidlitz, "Parthenogenesis and its Relation to other For Generation in the Animal Kingdom" ("Die Parthenogenes ihr Verhältniss zu den übrigen Zeugungs-Arten im Thierr Leipzig, 1872).

17 (i. 34). The Preformation-theory. This theory Germany, usually called "Evolutions-theorie," in distinction the "Epigenesis-theorie." As, however, in England, Franc Italy, the latter is, on the contrary, usually called the the evolution, evolution and epigenesis being used as synon terms, it appears better to call the former "the theory o formation." Recently Kölliker has called his "theory of h genous generation" "Evolutionism" (note 47). Cf. pr p. xxx.

18 (i. 37). Alfred Kirchhoff, "Caspar Friedrich Wol Life and Teaching in the Science of Organic Evolutic "Jenaische Zeitschrift für Naturwissenschaft," 1868, v p. 193.

19 (i. 43). Part of the writings left by Wolff have n been published. His most important works are the disser for the degree of doctor, *Theoria generationis* (1759), an model treatise "de formatione intestinorum" (on the form of the intestinal canal).—"Nov. Comment. Acad. Sc. Petro xii. 1768; xiii. 1769. Translated into German by M Halle, 1812.

20 (i. 51) Christian Pander, "*Historia metamorphoseos*,

um incubatum prioribus quinque diebus subit." Vicebergi, 17. (Dissertatio inauguralis.) "Contributions toward the story of the evolution of the chick within the egg." ("Beiträge r Entwickelungsgeschichte des Hühnchens im Eie." Würzrg, 1817.)

21 (i. 52). Karl Ernst Baer, "On the Evolution of Animals. bservations and Reflections" ("Ueber Entwickelungsgeschichte r Thiere. Beobachtung und Reflexion." 2 vols. Königsberg, 827–1837). In addition to this chief work, cf. "Story of the fe and Writings of Dr. Karl Ernst Baer, told by himself" 'Nachrichten über Leben und Schriften des Dr. Karl Ernst aer, mitgetheilt von ihm selbst." Petersburg, 1865).

22 (i. 60). Albert Kölliker. His "History of the Evolution of an and the Higher Animals" ("Entwickelungsgeschichte des enschen und der höheren Thiere"). The 2nd (corrected) edition, 876, contains (pp. 28–40) a catalogue of ontogenetic literature. n the newer contributions to this, cf. the "Jahresberichte ber die Leistungen und Fortschritte der Medicin" (Berlin), by irchow and Hirsch (the "History of Evolution," by Waldeyer); lso the "Jahresberichte über die Fortschritte der Anatomie und hysiologie," by Hofmann and Schwalbe (Leipzig); the "History f Evolution," by R. Hertwig and Nitsche. Most of Kowalevky's researches are contained in the "Memoires de l'Académie mpériale de St. Petersburg" (from the year 1866). Others are ublished in Max Schultze's "Archiv für mikroskopische natomie," and in other periodicals.

23 (i. 60). Theodor Schwann, "Microscopic Researches into he Identity in Structure and Growth of Plants and Animals" "Mikroskopische Untersuchungen über die Uebereinstimmung n der Structur und Wachsthum der Thiere und Pflanzen." Berlin, 1839).

24 (i. 69). Ernst Haeckel, the Gastræa Theory, phylogenetic lassification of the animal kingdom and homology of the germayers.—"Jenaische Zeitschrift für Naturwissenschaft," vol. viii. 874, pp. 1–56.

25 (i. 75). Ernst Haeckel, "The History of Creation." ondon, 1876.

26 (i. 81). Fritz Schultze, "Kant and Darwin." A co tribution to the history of the science of evolution. Jena, 18

27 (i. 81). Immanuel Kant, "Critique of Teleological Re son" ("Kritik der teleologischen Urtheilskraft"). 1790. § and § 79. Cf. also my "History of Creation," vol. i. p. 103.

28 (i. 83). Jean Lamarck, "Philosophie Zoologique, o Exposition des Considérations relatives à l'histoire naturelle d animaux," etc. 2 Tomes. Paris, 1809. Nouvelle édition, rev et précédée d'une introduction biographique par Charles Martin Paris, 1873.

29 (i. 88). Wolfgang Goethe on Morphology (zur Morph logie). The formation and re-formation of organic bodies. O Goethe's morphological studies, cf. Oscar Schmidt ("Goethe Verhältniss zu den organischen Naturwissenschaften." Je 1853). Rudolph Virchow, "Goethe as a Naturalist" (Berl 1861). Helmholtz, "On Goethe's Natural Scientific Work (Brunswick, 1865).

30 (i. 96). Charles Darwin. His chief work is "On t Origin of Species by means of Natural Selection" (1859).

31 (i. 99). Darwin and Wallace. The general outlines the theory of selection were discovered independently by Dar and Wallace. It does not, however, follow that the servi of the latter in furthering the science of evolution are at comparable with those of the former. As many opponents Darwin, especially the English Jesuit Mivart, have recen endeavoured to exalt Wallace at the expense of Darwin, and depreciate the latter, I take this opportunity of expressly ass ing that Darwin's services are very far the greater.

32 (i. 101). Thomas Huxley. In addition to the wo mentioned in the text, the following popular works are especi to be recommended: "On Our Knowledge of the Causes Phenomena in Organic Nature," and the "Elementary P siology" (1871).

33 (i. 101). Gustav Jaeger, "Zoological Letters" ("Zoologis Briefe." Vienna, 1876), and the "Text-book of General Zoolog ("Lehrbuch der Allgemeinen Zoologie." Stuttgart, 1875).

34 (i. 101). Friedrich Rolle, "Man, his Descent and Morality resented in the light of the Darwinian Theory, and on the is of Recent Geological Discoveries" ("Der Mensch, seine stammung und Gesittung im Lichte der Darwin'schen Lehre," .). Frankfort, 1866.

35 (i. 102). Ernst Haeckel, "Generelle Morphologie der ganismen." General outlines of the science of organic forms, chanically shown in accordance with the theory of descent as ormed by Charles Darwin. Vol. i., "General Anatomy;" . ii., "General History of Evolution." Berlin, 1866.

36 (i. 103). Charles Darwin, "The Descent of Man, and lection in Relation to Sex." 2 vols. London, 1871.

37 (i. 108). Karl Gegenbaur, "Outlines of Comparative atomy" ("Grundzüge der vergleichenden Anatomie." Leipzig. d ed., 1870). "Elements of Comparative Anatomy" ("Grundriss r vergleichenden Anatomie." 3rd (improved) edition, 1874).

38 (i. 114). Migration-theory. Moritz Wagner, "The Darinian Theory and the Law of Migration of Organisms" ("Die arwin'sche Theorie und das Migrations-gesetz der Organmen." Leipzig, 1868). August Weismann, "On the Influence Isolation in the Formation of Species" ("Ueber den Einfluss r Isolirung auf die Artenbidung." Leipzig, 1871).

39 (i. 116). Carus Sterne, "Evolution and Dissolution" ("Werden und Vergehen"). A popular history of the evolution of ature as a whole. Berlin, 1876. Agassiz a "founder" of atural science. "Gegenwart." Berlin, 1876.

40 (i. 117). Ernst Haeckel, "The Chalk-sponges" ("Die alkschwämme; Calcispongien oder Grantien." Berlin, 1872). monograph and an attempted solution of the problem of the rigin of species. Vol. i., "Biology of Chalk-sponges;" vol. ii., Classification of Chalk-sponges;" vol. iii., "Atlas of Chalkponges" (with 60 plates).

41 (i. 124). On the Individuality of Cells and recent reforms the cell-theory, cf. my "Individualitätslehre," or "Tectologie" "Generelle Morphologie," vol. i. pp. 239–274). Rudolf irchow, "Cellular Pathologie." 4th edition. Berlin, 1871.

42 (i. 130). "The Plastid-theory and the Cell-theory "Jenaische Zeitschrift für Naturwissenschaft," 1870, vol. 492.

43 (i. 138). Gegenbaur, "On the Structure and Evolutio Vertebrate Eggs with Partial Yelk-cleavage."—"Archiv f. A u. Phys." 1861, p. 491.

44 (i. 153). Ernst Haeckel, "On Division of Labour in Na and Human Life," in the collection of Lectures by Virc Holtzendorf, 1869. Sect. 78. 2nd edition.

45 (i. 160). Monogony (*Generatio neutralis*). On the va forms of asexual reproduction (Schizogony, Sporogony, etc. "Generelle Morphologie," vol. ii. pp. 36–58.

46 (i. 160). Amphigony (*Generatio sexualis*). On the va forms of sexual reproduction (Hermaphroditism, Gonocho etc.), see "Generelle Morphologie," vol. ii. pp. 58–69.

47 (i. 168). Fitful evolution and gradual evolution. theory of fitful evolution has recently been developed esp by Kölliker, who, under the title of heterogeneous gene opposes it to gradual evolution as maintained by us ("Ze f. Wissens. Zool.," vol. xiv. 1864, p. 181, and "Alcyonaria," pp. 384–415). This theory is distinguished by assuming *unknown causes* for the "fitful evolution of species," a so "great law of evolution" (an empty word indeed!). contrary, we see, with Darwin, in the facts of Heredi Adaptation sufficient known (partly inner, partly ex physiological causes, which explain the gradual evolut species under the influence of the struggle for existence.

48 (i. 170). Immaculate Conception never occurs vertebrate tribe. On the other hand, parthenogenesis freq occurs among Articulated Animals (*Arthropoda*) (note 16).

49 (i. 171). Fertilization of Flowers by insects. Darwin on "The various contrivances by which Briti Foreign Orchids are fertilized by Insects." Hermann Mü "The Fertilization of Flowers by Insects, and the corr adaptations of both" ("Die Befruchtung der Blumen Insecten und die gegenseitigen Anpassungen Beider").

tion to our knowledge of causal connection in organic re. Leipzig, 1873.

O (i. 178). The Process of Fertilization has been very usly viewed, and was formerly often regarded as an ely mysterious process, or even as a supernatural miracle. ow appears no more "wonderful or supernatural" than the ess of digestion, of muscular movement, or of any other iological function. For the earlier views, cf. Leuckart, cle "Zeugung" (generation) in R. Wagner's "Dictionary hysiology," 1850.

51 (i. 179). Monerula. The simple, very transient, kernel- condition, which we briefly call the "monerula," and, in rdance with the fundamental law of Biogeny, regard as a ngenetic reproduction of the phylogenetic Moneron parent- n, appears to vary to some extent in different organisms, cially in the matter of duration. In those cases in which o longer occurs, and in which the kernel of the fertilized persists wholly or partially, we may regard this phenomenon later, kenogenetic curtailment of Ontogeny.

52 (i. 181). The Plasson of the monerula appears, mor- logically, a homogeneous and structureless substance, like of the Moneron. This is not contradicted by the fact that ascribe a very complex molecular structure to the plastidules, "plasson-molecules," of the monerula; this latter will rally be more complex in proportion as the organism which ntogenetically constitutes is higher, and as the ancestral s of that organism is longer, in proportion as the preceding esses of Heredity and Adaptation are more numerous.

53 (i. 182). The Fundamental Significance of the Parent-cell, ytula, as the foundation-stone of the young organism in the se of development, can only be rightly appreciated, if the taken in its constitution by the two generating cells is tly appreciated, the part taken by the male sperm-cell and he female egg-cell.

54 (i. 183). The One-celled Germ-organism, like the act of lization from which it results, has been very variously

viewed. Cf. on this subject, in addition to the four impor works, here quoted, by Auerbach, Bütschli, Hertwig, and Str burger, the most recent annals of the progress of the histor evolution (Waldeyer in Virchow-Hirsch's "Jahresberichte Berlin; Hertwig in Hofmann-Schwalbe's "Jahresberichte Leipzig).

55 (i. 185). Protozoa and Metazoa. Cf. vol. i. p. 248; ii. The Protozoa and Metazoa are genetically and anatomically very distinct, that the former, as Protista, may even be exclu entirely from the animal kingdom, and may be regarded as neutral intermediate kingdom between the plant and anim kingdoms.—"Generelle Morphologie," vol. i. pp. 191–230. A cording to this view the Metazoa alone are really animals.

56 (i. 186). The Unity of the Zoogenetic Conception, resu ing from the Gastræa-theory, has as yet not been destroyed the numerous attacks directed against that theory: for none these attacks have succeeded in substituting anything positi by pure negation no advance can be made in this dark difficult subject.

57 (i. 187). The Egg-cleavage and Gastrulation of Man represented diagrammatically in Figs. 12–17 of Plate II., is probably in no essential way different from that of the Ra which has as yet been most closely examined in this point.

58 (i. 188). Ernst Haeckel, "Arabian Corals" ("Arabi Korallen"). "A Journey to the Coral Banks of the Red Sea, a Glimpse into the Life of Coral Animals. A popular lect with scientific explanations." With 5 coloured plates, and woodcuts. Berlin, 1876.

59 (i. 189). The Number of the Segmentella, or cleav cells, increases, in the original, pure forms of palingenetic cleavage, in regular geometric progression. But the poin which this proceeds varies in the various archiblastic anim so that the Morula, as the final result of the cleavage-pro consists sometimes of 32, sometimes of 64, sometimes of cells, and so on.

60 (i. 189). The Mulberry-germ, or Morula. The

entella, or cleavage-cells, which constitute the Morula at the se of palingenetic egg-cleavage, generally appear entirely nilar, with morphological difference in size, form, or constitution. This does not, however, hinder the fact that these lls have separated, even during cleavage, into animal and getable cells, have differentiated physiologically, as is indicated Figs. 2 and 3, Plate II., as probable.

61 (i. 189). The Bladder-germ of Archiblastic Animals *blastula*, or *blastosphæra*), which is now commonly known as he germ-vesicle, or, more accurately, as the "germ-membrane esicle," must not be confused with the essentially different germ-vesicle" of amphiblastic mammals, which is better called he "intestinal-germ vesicle" (*gastrocystis*). The gastrocystis nd the blastula are still often united under the name of "germesicle, or *vesicula blastodermica*." Cf. vol. i. p. 290.

62 (i. 192). The Definition of the Gastrula was first stablished by me in 1872, in my "Monograph of Chalk-sponges" vol. i. pp. 333, 345, 466). There I already gave due weight to he "extremely great significance of the gastrula in reference o the general Phylogeny of the animal kingdom" (p. 333). "The fact that these larval forms re-occur in the most different nimals, cannot, I think, be sufficiently estimated, and bears lain witness to the former common descent of all from the Gastræa" (p. 345).

63 (i. 194). The Uniaxial Outline of the Gastrula is, on ccount of the two different poles of the axis, more accurately described as a diplopolic uniaxial form (a sternometric outline: conoid-form, or cone). Cf. my "Promorphology" ("Generelle Morphologie," vol. i. p. 426).

64 (i. 194). Primitive Intestine and Primitive Mouth. My distinction of the primitive intestine and primitive mouth (*protogaster* and *protostoma*) from the later, permanent intestine and mouth (*metagaster* and *metastoma*) has been variously attacked; it is, however, as much justified as the distinction of the primitive kidney from the permanent kidney, of the primitive vertebræ from the permanent vertebræ. The primitive intestine

forms but a part of the permanent intestine, and the prim mouth (at least in the higher animals) does not becom permanent mouth.

65 (i. 196). Primitive germ-layers (*blastophylla*). As two primary germ-layers (*entoderma* and *exoderma*) origin form the sole histogenetic rudiment of the whole body, and the *mesoderma*, the nutritive yelk, and all other accessory p of the germ have developed only secondarily from the for I consider it very important to distinguish between the pri and secondary germ-layers. The latter, to distinguish from the former, might be called "after germ-layers" (*telasma*).

66 (i. 201). Unequal Cleavage and Hood-gastrula *mentatio inæqualis* et *Amphigastrula*). Next to Amphibi most accessible examples for observation of unequal cle and the Amphigastrula are afforded by the indigenous bodied Animals (*Mollusca*) and Worms (Snails and M Earth Worms and Leeches).

67 (i. 202). The Colour of Amphibian-eggs is occasion the accumulation of dark colouring-matter at the animal p the egg. In consequence of this the animal-cells of the ex appear darker than the vegetative cells of the entoderm most animals the reverse is the case; the protoplasm o entoderm cells being usually darker and more coarsely gran (vol. i. p. 197).

68 (i. 207). Hood-gastrula of Amphibia. Cf. Robert R "On the Evolution of Batrachia" ("Ueber die Entwickelun Batrachier," p. 126; Plate XII. Figs. 3–7). Stricker's "M of Tissues" ("Handbuch der Gewebelehre," vol. ii. p. 1 1202; Figs. 399–402). Goette, "History of the Evoluti *Bombinator*" ("Entwickelungsgeschichte der Unke," p. Plate II. Figs. 32–35).

69 (i. 214). Hood-gastrula of Mammals. Eduard Beneden, "La maturation de l'œuf, la fécondation et les pren phases du développement embryonnaire des Mammifères, d' des recherches faites chez le lapin." Brussels, 1875. No fi

given with these "Communication préliminaire;" Van neden's description is, however, so clear, so thorough and care-, that they afford an entirely satisfactory insight into unequal g-cleavage and the formation of the Hood-gastrula in Mammals. l other observers, who have studied the germination of Mam-alian eggs (among the most recent Kölliker, Rauber, and ewson may be especially mentioned), have overlooked or iled to recognize the important features discovered by Van eneden.

70 (i. 218). The Disc-gastrula (*Disco-gastrula*) of Osseous ishes (*Teleostei*). Van Bambeke, "Recherches sur l'embry-logie des poissons osseux." Brussels, 1875. The transparent ish-eggs, in which I observed discoid cleavage (*Segmentatio iscoidalis*) and the formation of the Disc-gastrula by invagination, e accurately described in my article on "The Gastrula and gg-cleavage of Animals" ("Jen. Zeitschrift für Naturwis-nschaft," 1875, vol. ix. p. 432–444; Plates IV., V.). On the isc-gastrula of *Selachii*, cf. Balfour, "The Development of lasmo branch Fishes."—"Journ. of Anat. and Physiol.," vol. x. 517; Plates XX., XXIII.

71 (i. 221). Yelk-cells of Birds. The cell-like constituent arts, which occur in great number and variety in the nutritive elk of Birds and Reptiles, as in most Fishes, are nothing less han true cells, as His and others have asserted. This does not ean that in this matter a distinct limit everywhere exists etween the nutritive and the formative yelks, as in our oceanic ish-eggs (Figs. 42, 43, note 70). On the contrary, *originally* phylogenetically) the nutritive yelk originated from part of the ntoderm.

72 (i. 223). Egg-cells of Birds. Notwithstanding the large utritive yelk, the "after-egg" (*metovum*) of Birds and Reptiles s, in form-value, a single cell. The very small, active protoplasm f the "tread" does, however, indeed fall far short, in volume, f the huge mass of the yellow yelk-ball. The bird's eggs are bsolutely the largest cells of the animal body. Cf. note 43, and Eduard van Beneden, "Recherches sur la composition et la

signification de l'œuf." Brussels, 1870. Hubert Ludwig Egg-structure in the Animal Kingdom" ("Ueber die Eib in Thierreiche." Würzburg, 1874).

73 (i. 226). Discoidal cleavage (*Segmentatio discoida* Bird's eggs. Cf. Kölliker, "History of the Evolution c and the Higher Animals" ("Entwickelungsgeschichte de schen und der höheren Thiere." 2nd edition, 1876, pp. Figs. 16–22).

74 (i. 227). Disc-gastrula (*Disco-gastrula*) of Bird Rauber, "On the Place of the Chick in the System of tion" ("Ueber die Stellung des Hühnchens im Entwick plan"). Leipzig, 1876. Foster and Balfour, "The Elen Embryology." London, 1874.

75 (i. 231). Bladder-gastrula (*Perigastrula*) of Art Animals (*Arthropoda*). Cf. Bobretzky, "Russian Essay Germ-history of Astacus and Palæmon." Kiew, 1873. own article on the gastrula and egg-cleavage.—"Jen. Ze für Naturwissenschaft." Vol. ix. pp. 444–452, Plate VI.

76 (i. 234). The Four-layer Theory, which was first stated by Baer in 1837 ("Entwickelungsgeschichte der vol. ii. pp. 46, 68), and which we have here carried out l yet appears the only form of the germ-layer theory, on comparative observation of all higher animals, su universal law of germination for all and at the same tim the inconsistent reputations of many observers.

77 (i. 239). Caspar Friedrich Wolff first indicated th layer Theory (note 76). Cf. the remarkable sentence, qu vol. i. p. 45, from his pregnant work on the formatio intestinal canal (note 19).

78 (i. 240). The Four Main Types of Gastrulation are diagrammatically distinguished in Plates II. and III. Tables III. and IV. (vol. i. pp. 241, 242), are of course co by intermediate forms. These are transitions both betw primordial and the unequal forms, and between the primor the superficial forms; similarly, the unequal form of egg-c is connected by twixt-forms with the discoidal forms, whic

ain, perhaps, connected in the same way with the superficial

9 (i. 241). The Gastrulation of the various classes of als has been far too little studied to enable us thoroughly ummarize the distribution of the various forms within the ate classes. Yet it is already evident that primordial egg-age and the formation of the Archigastrula occur in the st classes of each tribe.

0 (i. 243). The Rhythm of egg-cleavage is by no means as lar as might appear from the four first examples in the five s. There are, on the contrary, many variations, and not quently an entirely irregular and very variable sequence of bers occurs (especially in discoided cleavage).

1 (i. 246). Definition of the Type. Cf. Gegenbaur, ements of Comparative Anatomy," 1874, p. 59.

2 (i. 246). Types and Phyla. According to the prevailing pe-theory," the types of the animal kingdom are *parallel*, entirely independent; according to my "Gastræa-theory," he contrary, they are divergent tribes, connected at the ; according to the view of Claus and other opponents, the r is no essential distinction.

3 (i. 248). The one-celled condition of Infusoria entirely ids their morphological comparison with Metazoa. Cf. my le "On the Morphology of Infusoria" ("Jen. Zeitschrift Naturwissenschaft" 1873, vol. vii. p. 516–568).

34 (i. 257). The axes of the Vertebrate outline. Cf. my omorphology" (Stereometry of Organisms).—"Generelle phologie," vol. i. pp. 374–574. "Singly double-outlines" *leura*), p. 519. "Bilateral-symmetrical" forms in the fourth ification of the word.

35 (i. 255). The Primitive Vertebrate Type, as it is repre-ed in Figs. 52–56, is a hypothetic diagram, which is principally ded on the outline of the Amphioxus, but in which the parative Anatomy of Ascidia and Appendicularia on the side, of Cyclostomi and Selachii on the other, is regarded. diagram is by no means meant to be an "exact figure," but

a provisional stage in the hypothetic reconstruction of the unknown, long extinct parent-form of Vertebrates, an "Ani type."

86 (i. 258). Only very uncertain assumptions can be m as to the sense-organs of the hypothetic parent-form, for the organs, more than any others, have been subject to adaptation and in Ascidia, as in the Amphioxus, have probably been m atrophied. The earliest Vertebrates probably inherited a p of eyes of very simple character and a pair of simple ear-vesic from Worms.

87 (i. 267). The primitive kidneys were perhaps alread metameric in the hypothetic parent-form of Vertebrates, so that in addition to the two longitudinal main canals (primitive kidney ducts) numerous transverse tubes (segmental canals) were connected with these main canals, a pair in each metamere of the middle part of the body. Perhaps these already opened through ciliated funnels into the body-cavity (*cœloma*), as is now the case in Annelids, and, according to Balfour, in the embryos of Selachii. Cf. Balfour, "Development of Elasm branch Fishes."—"Quarterly Journal of Microscopical Science New Series, vol. xiv. p. 323; "Journal of Anat. and Physiol vol. x.

88 (i. 273). The germination of Primitive Vertebrates. (with Table VI., Table VII. (vol. i. p. 327), Table XI. (p. 46 also the diagrammatic figures in Plates IV. and V. with expla tion (p. 321).

89 (i. 276). The Germ-forms of the earliest Vertebrates they are represented in diagrammatic cross sections in F 62–69, can only, of course, be approximately guessed, and w the aid of Comparative Anatomy and Ontogeny. Th hypothetic diagrams, therefore, by no means claim to be cepted dogmatically, any more than do those in Figs. 52- (Cf. note 85.)

90 (i. 280). Main incidents in Vertebrate germination. the main palingenetic incidents here enumerated, perhaps sixth, ninth, and tenth originally occurred in a very

nt form. The other seven now appear to be pretty well blished.

91 (i. 285). The flat germ-disc of Birds, which even now, in opinion of most embryologists, represents the first starting-nt in the formation of the embryo, and to which all other m-forms have been referred, is, on the contrary, a late and ch modified germ-form, which has arisen in consequence of extension of the gastrula over the greatly enlarging nutritive k.

92 (i. 289). Site of Fertilization. In Man, as in other mmals, fertilization of the eggs probably usually takes place the oviduct: here, the eggs which, at the rupture of the afian follicles, have emerged from the female ovary and sed into the outer opening of the oviduct, meet with the ive sperm-cells of the male seed, which, during copulation, etrated into the uterus, and from there passed into the inner ning of the oviduct. Rarely, fertilization occurs even on the ry, or not till within the uterus. (Cf. Chapter XXV.)

93 (i. 293). The origin of the mesoderm in Mammals, as in er animals, is, at present, among the most obscure and con-ed points of Ontogeny. Remak, Balfour, and others derive rom the entoderm, Kölliker and others from the exoderm. ldeyer, His, and others assert that both primary germ-layers e part in the formation of the mesoderm. The last assump-is, I believe, correct. (Cf. notes 76, 77.)

94 (i. 297). The Germ-shield (*Notaspis*). The ordinary w, that the germ-shield (= Remak's "Doppelschild") is the liest rudiment of the actual embryo, results in many erroneous clusions. It is, therefore, necessary to point out especially t the germ-shield represents the first well-defined central sal part of the embryo.

95 (i. 317). Body Wall and Intestinal Wall. The morpho-ical distinction between the body wall and the intestinal wall, tainly primordial, is probably referable to the simple primary m-layers of the Gastræa. If the skin-fibrous layer is derived n the exoderm, and the intestinal-fibrous layer from the

entoderm, this most simply explains the progressive develop of this distinction, which may be traced through the seri Worms, and up to Vertebrates.

96 (i. 320). Palingenetic and Kenogenetic germination. the germ-history of Vertebrates no clear conception of embryological process has yet been attained, because all aut have started from the higher Vertebrates (usually from Chick) and have assumed that the form of evolution occur in this case is original and typical. It is only since the g history of the Amphioxus has taught us the palingenetic, r original form of germination of Vertebrate organisms, th have been enabled, by Comparative Ontogeny (and especiall the principles of the Gastræa theory), rightly to understand to explain phylogenetically the kenogenetic forms of germin of higher Vertebrates.

97 (i. 321). The Diagrams in Plates IV. and V. are as s and abstract as possible, in order to render the desired g explanation as easy as possible.

98 (i. 346). Primitive Vertebræ and Metamera. Fo right conception of "primitive vertebral" structure it is cially necessary to point out that the primitive vertebr much more than their name indicates. They must, in fi conceived as individual, consecutive sections of the which have arisen one after the other, as true "metame consecutive pieces ("Generelle Morphologie," vol. i. p. Each primitive vertebra of a Vertebrate, like each trunk-se or metameron of an Annelid or Arthropod, contains a essential, morphological constituent parts, characteristic corresponding animal-tribe.

99 (i. 349). Origin of the Primitive Vertebræ. My c tion of these as individual, morphological "consecutive p which, like the metamera of Cestods and Annelids, have by terminal budding from a single unarticulated piece, ha much attacked. I therefore emphatically remark that understand this process in the widest sense. In both case is certainly a reproduction of individual, like parts, whicl originated (in time and space) consecutively.

100 (i. 361). The agreement among the germ-forms of ious Mammals is instructive especially because it shows us w, by diversity in the mode of evolution, the most diverse actures can originate from one and the same form. As we ually see this in germ-forms, we may hypothetically assume same to have occurred among tribe-forms. Moreover, s agreement is never absolute identity, but always only very greatest similarity. Even the germs of the various ividuals of a species are never actually identical.

101 (i. 366). The law of the ontogenetic connection of stematically allied animal-forms has many apparent exceptions. ese are, however, fully explained by the adaptation of the rm to kenogenetic conditions of existence. Where the palinenetic form of evolution of the germ has been accurately ansmitted by heredity, that law is always in force. Cf. Fritz üller, "Für Darwin" (note 111).

102 (i. 367). Earliest human germs. Cf. Kölliker, "History the Evolution of Man" ("Entwickelungsgeschichte des Menhen." 2nd edition, 1876, pp. 303–319). Also Ecker, "Icones ysiologicæ." Leipzig, 1859. Plates XXV.–XXXI. The rliest human germs which have yet been certainly recognized, ere from twelve to fourteen days old, and were observed by rof. Allen Thomson, of Glasgow. No opportunity has ever curred for the observation of earlier germs.

103 (i. 369). Human germs of three weeks (twenty to twentyne days) exhibit in their whole structure that phylogenetic stage evolution which, among extant Vertebrates, is represented by e Cyclostomi (Lampreys and Hags, vol. ii. p. 103), and which ust be referable to extinct Monorhine ancestors of similar ructure.

104 (i. 370). Human germs of four weeks (twenty-five to irty days), on the whole, exhibit in their whole structure that hylogenetic stage of evolution, which is exhibited in Sharks nd Rays, among extant Vertebrates, and which is referable to imilar extinct Primitive Fish ancestors (*Proselachii*). Of course his comparison is affected by various kenogenetic modifications

(both heterotopic and heterochronic), just as in the for
(Cf. note 108.)

105 (i. 374). The nose of Nosed-apes is much more diff
from that of other Apes than from that of Man. Morew
even the extreme variety and variability in the external for
of the human nose shows how small is the morphological val
of this organ, so important to the physiognomy.

106 (i. 383). The bladder-like form of the human Allant
Cf. W. Krause, "On the Allantois in Man" ("Ueber die Allan
tois des Menschen."—"Archiv für Anat. u. Physiol.," 1875, p. 21
Plate VI.).

107 (i. 400). The navel-cord (*funiculus umbilicalis*), E
the placenta, is an organ shared by Man exclusively with Pl
cental Animals. Cf. Chap. XIX. pp. 155–168, and Figs. 200, 2
On the more minute structure of this organ, and on the spe
features of the embryonic blood-circulation, cf. Kölliker, "E
tory of the Evolution of Man." 2nd edition, 1876, pp. 319–3

108 (i. 401). The Kenogeny of Man. In pointing out
phylogenetic significance of the separate incidents and period
human germ-history, and in explaining them by reference to
responding processes and stages in the tribal history of our ani
ancestors, we must always bear in mind that in Man, as i
higher animals, the original palingenetic cause of germina
has undergone much kenogenetic modification in consequen
many adaptations to the very various conditions of embry
life, that it has thus been much violated and contracted.
higher the organism develops, the more are especially t
earliest stages of evolution abbreviated.

109 (i. 404). The sections of human germ-history, of w
only four larger and ten smaller are mentioned here in refer
to their phylogenetic significance, allow of much more divi
if their comparative Ontogeny is minutely examined.
phylogenetic significance may also be very well explained
fitting reference to kenogenetic displacements in place and
(vol. i. p. 13).

110 (i. 405). Figures of human embryos in all stage

m-history were given in very beautiful detail by M. P. Erdl ty years ago: "The Evolution of Man, and of the Chick in Egg" ("Die Entwickelung des Menschen, und des Hühnchens Ei." Leipzig, 1845).

111 (i. 409). Fritz Müller, "Für Darwin." Leipzig, 1864. very excellent little book, in which the modification of the damental law of Biogeny (with reference to the Phylogeny of ustacea) are explained for the first time.

112 (i. 413). The Method of Phylogeny is of the same rphological value as the well-known method of Geology, and y, therefore, claim exactly the same scientific acceptation. the excellent discourse by Eduard Strasburger, "On the portance of Phylogenetic Methods in the Study of Living ings."—"Jenaische Zeitschrift für Naturwissenschaft," 1874, l. viii. p. 56.

113 (i. 415). Johannes Müller, "On the Structure and Vital enomena of *Amphioxus lanceolatus*."—Transactions of the rlin Academy, 1844.

114 (i. 415). Recent works on the Amphioxus. W. Rolph d E. Ray Lankester especially have recently added to our owledge of the organology of the Amphioxus, Wilhelm Müller d P. Langerhans to that of its histology. The literature of s subject is fully represented by W. Rolph, in his "Researches o the Structure of the Amphioxus" ("Untersuchungen über n Bau des Amphioxus."—"Morpholog. Jahrb.," vol. ii. p. 87, ates V. and VII.), and in P. Langerhans, "On the Anatomy of Amphioxus" ("Zur Anatomie des Amphioxus."—"Archiv. Mikr. Anat.," vol. xii. p. 290, Plates XII.–XV.).

115 (i. 416). Acrania and Craniota. The separation of rtebrates into Skull-less Animals (*Acrania*) and Skulled imals (*Craniota*), which I first indicated in 1866 in my Generelle Morphologie," appears to me absolutely essential for phylogenetic explanation of the Vertebrate-tribe.

116 (i. 428). Max Schultze, "History of the Evolution of tromyzon" ("Entwickelungsgeschichte von *Petromyzon*." Haarn, 1856). The Ontogeny of the Hags, which promises very portant results, is yet, unfortunately, entirely unknown.

117 (i. 430). Savigny, "Mémoires sur les Animau Vertébres." Vol. ii., Ascidies, 1816. Giard, "Recherc les Synascidies."—"Archives de Zoologie Experimentale,' 1872.

118 (i. 435). Syn-ascidia and Echinoderms. The Corm of Echinoderms, which I explained in 1866 ("Generel phologie," vol. ii. p. lxiii), and which has been much atta "paradoxical," is as yet the sole theory attempting the explanation of this remarkable group of animals.

119 (i. 442). Kowalevsky, "History of the Evolutio Amphioxus and of Simple Ascidians" ("Mémoires de l'A S. Petersbourg." 7 Serie. Tom. x. and xi. 1867–8).

120 (i. 450). The metameric structure of the Am which is indicated in its nerve and muscle systems, und shows that the notochord exists in Vertebrates previous metameric structure, and consequently that it is inherit unarticulated Chorda Animals.

121 (i. 454). The Metamorphosis of the Amphioxus, which the larva passes into the adult form, is not known in all its details. This does not, however, a extraordinarily important bearing of the thoroughly earliest incidents in its germination on the palingenesis brates.

122 (i. 455). Fertilization of Ascidia (*Phallusia mam* Eduard Strasburger, "On Cell-structure and Cell-divis Studies of Fertilization." 2nd edition. Jena, 1876, Plate VIII.

123 (i. 462). Kupffer. The tribal relation of A Vertebrates ("Archiv für Mikros. Anat.," 1870, vol 115–170). Oscar Hertwig, "Researches into the Stru Evolution of the Cellulose Mantles of Tunicata" ("chungen über den Bau und die Entwickelung des Mantels der Tunicaten"). Richard Hertwig, "Contri Knowledge of Ascidian Structure" ("Beiträge zur K des Baues der Ascidien."—"Jenaische Zeitschrift für N senschaft," 1873, vol. vii.).

124 (i. 464). The Phylogenetic Importance of the Amphi-
as cannot be too highly insisted on. Without knowledge of
Anatomy and Ontogeny, the origin of Vertebrates would be
irely dubious, and their descent from Worms would appear
redible.

125 (i. 467). The Ontogenetic Cell-pedigree, as it is repre-
ted, with reference to the Amphioxus, in Table XI., probably
ds good, in its most important features, for all Vertebrates,
d, therefore, also for Man. For, more than any other form,
e Amphioxus by strict Heredity has accurately retained its
lingenesis. This histogenetic cell-pedigree is apparently well
tablished as regards most and the chief features; on the other
nd, it yet appears doubtful with regard to the origin of the
imitive kidneys, the testes, and ovaries.

126 (ii. 4). Milne-Edwards, "Leçons sur la Physiologie
omparée," vol. ix.

127 (ii. 6). Eternity of Organic Life. According to the
onistic view, organic life is a further form of evolution of the
organic word-processes, and had a beginning in time on our
anet. In opposition to this, A. Fechner, among others, in his
Thoughts on the Creation and Evolution of Organisms," has
ted certain opposed "kosmorganic phantasys" which appear
tirely irreconcilable with the ontogenetic facts given here.

128 (ii. 18). Bernhard Cotta ("Geologie der Gegenwart,"
66; 4th edition, 1874) and Karl Zittel ("Aus der Urzeit;"
ünchen, 1875, 2nd edition) have made some excellent remarks
the duration and the whole course of the organic history of
e world.

129 (ii. 21). August Schleicher, "The Darwinian Theory
d Philology" ("Die Darwin'sche Theorie und die Sprach-
issenschaft." Weimar, 1863. 2nd edition, 1873).

130 (ii. 25). At first sight, most polyphyletic hypotheses
pear more simple and easy than do monophyletic, but the
rmer always present more difficulties the more they are
nsidered.

131 (ii. 25). Those physiologists who desire an experi-

mental proof of the theory of descent, merely thereby prov extraordinary ignorance of the morphological scientific fa lating to this matter.

132 (ii. 30). Spontaneous generation.—"Generelle phologie," vol. i. pp. 167–190. "Monera and Spontaneous ration."—"Jenaische Zeitschrift für Naturwissenschaft," vol. vi. pp. 37–42.

133 (ii. 33). The Absence of Organs in Monera. In that Monera are "organisms without organs," we understa definition of organs in a morphological sense. In a physiol sense, on the other hand, we may call the variable pl processes of the body of the Moneron the "*pseudopodia*" o

134 (ii. 36). Induction and Deduction in Anthrop "Generelle Morphologie," vol. i. pp. 79–88; vol. ii. p "History of Creation," vol. ii. p. 357.

135 (ii. 42). Animal Ancestors of Man. The num species (or, more accurately, form-stages, which are disting as "species") must, in the human ancestral line (in the co many millions of years!), have amounted to many thou the number of genera to many hundreds.

136 (ii. 47). Following Elsberg, we give the name of tidules" to the "molecules of plasson," to the smallest lik of that albuminous substance which, according to the "p theory," is the material substratum of all the active phen of life. Cf. my work on "The Perigenesis of Plasti ("Perigenesis der Plastidule oder Wellenzeugung der I theilchen." Berlin, 1876). This is an attempt to e mechanically the elementary processes of evolution.

137 (ii. 49). Bathybius and the free protoplasm of depths. Cf. my "Studies on Monera and other Pr Leipzig, 1870, p. 86. The most recent observations on Bathybius are those of Dr. Emil Bessel, who found this f the coast of Greenland (in Smith's Sound), at a depth o 550 ft. He noticed very active amœboid movements i as well as the assumption of foreign particles (carmin "It consists of nearly pure protoplasm, tinged most inter

lution of carmine in ammonia. It contains fine gray granules considerable refracting power, and besides the latter a great nber of oleaginous drops, soluble in ether. It manifests very rked amœboid motions, and takes up particles of carmine, etc." Packard, "Life Histories of Animals, including Man." New rk, 1876.

138 (ii. 50). The Philosophical Importance of Monera in laining the most obscure biological questions cannot be iciently emphasized. Monograph of Monera.—"Jenaische tschrift für Naturwissenschaft," vol. iv., 1868, p. 64.

139 (ii. 54). The Nature and Significance of the Egg-cell can y be philosophically understood by means of phylogenetic mination.

140 (ii. 58). Synamœba. Cienkowski, "On the Structure Evolution of Labyrinthula" ("Uber den Bau und die Entwicang der Labyrinthuleen."—Arch. für Mikrosk. Anat., 1870, iii. p. 274). Hertwig, "Microgromia Socialis."—*Ibid.*

141 (ii. 61). Catallacta, a new Protista-group (*Magosphæra nula*). See "Jenaische Zeitschrift für Naturwissenschaft," vi., 1871, p. 1.

142 (ii. 66). Haliphysema and Gastrophysema. Extant straeads. See "Jenaische Zeitschrift für Naturwissenschaft," xi., 1876, p. 1, Plates I.–VI.

143 (ii. 70). The five first stages in the evolution of the mal body, which are compared in Table XVII., and which common to Man and all higher Animals, are established ond all doubt as existing in the Ontogeny of most extant mals. As Comparative Anatomy shows that corresponding m-stages yet exist in the system of the lower animals, we y assume, in accordance with the fundamental law of Biogeny, t similar forms existed phylogenetically as most important estral forms.

144 (ii. 77). On the distinction of the axes, and on the metric outline of the animal body, see "*Promorphologie*" Generelle Morphologie," vol. i. pp. 374–574).

145 (ii. 87). The hermaphrodite structure of our ancestral

series was perhaps transmitted from the Chorda Animals eve
far as the lower stages of Vertebrate ancestors. Cf. Chapter X

146 (ii. 89). I am inclined to regard the Appendicular
living Chorda Animals of the present day; they are the
Invertebrates permanently possessing a notochord, and the
by many other peculiarities, distinguished from genuine T
cates.

147 (ii. 105). Metamorphosis of Lampreys. That the l
Ammocœtes change into Petromyzon was known two hun
years ago (1666) to the fisherman Leonhard Baldner of S
burg; but this observation remained unrecognized, and
modification was first discovered by August Müller in
("Archiv für Anat.," 1856, p. 325). Cf. Siebold, "The F
water Fishes of Central Europe" ("Die Süsswasserfische
Mittel-Europa," 1863).

148 (ii. 114). Selachii as Primitive Fishes. The old dis
as to the systematic position and kindred of Selachii were
definitely settled by Gegenbaur, in the introduction to his cla
work on "The Head-skeleton of Selachii."

149 (ii. 118). Gerard Krefft, "Description of a Gigantic
phibian;" and Albert Günther, "Ceratodus, and its Syste
Position."—"Archiv für Naturgeschichte," 37, 1871, vol.
321; also "Phil. Trans.," 1871, Part II. p. 511, etc.

150 (ii. 129). The duration of metamorphosis of Am
varies much in the different forms of Frogs and Toads, the
forming a complete phylogenetic series from the original,
complete form, to the later, much shortened and vitiated he
of modification.

151 (ii. 129). "All the histological features of the
Salamander (*Salamandra maculata*) force the impression t
belongs to an entirely different epoch of terrestrial life tha
of the Water Salamander (*Triton*), externally so similar."—
Remak ("Entwickelung der Wirbelthiere," p. 117).

152 (ii. 130). Siredon and Amblystoma. Very various
have lately been expressed as to the phylogenetic significa
be attributed to the much-discussed modification of the M

l into an Amblystoma. Cf. on this subject especially
; Weismann, in "Zeitsch. für wissensch. Zoologie," vol.
lup., pp. 297–334.

(ii. 131). The Leaf-frog of Martinique (*Hylodes mar-
is*) loses its gills on the seventh day, its tail and yelk-sac
eighth day of egg-life. On the ninth or tenth day after
ation the complete frog emerges from the egg.—Bavay,
Hylodes Martinicensis et ses Metamorphoses." "Journal.
l. par Grevais," vol. ii. 1873, p. 13.

(ii. 133). "Homo diluvii testis" = Andrias Scheuchzeri.
bone of an ancient evil-doer; Soften, stone, the heart of
w children of evil" (Diaconus Miller). Quenstedt,
erly and Now" ("Sonst und Jetzt," 1856, p. 239).

(ii. 133). The Amnion-structure of the three higher
rate-classes, wanting in all lower Vertebrates, has no
ion with the similar, but independently acquired Amnion-
re (analogous, but not homologous) of higher Arthro-
nimals (*Arthropoda*).

(ii. 138). The former existence of a Protamnion, the
n parent-form of all Amniota, is undoubtedly shown by
nparative Anatomy and Ontogeny of Reptiles, Birds, and
ls. No fossil remains of such a Protamnion have, how-
t been discovered. They must be sought in the Permian
oniferous formation.

(ii. 147). The former organisation of the Protamnionalia
e hypothetically reconstructed from the Comparative
y of the Salamander, Lizards, and Beaked Antimalia
orhynchus).

(ii. 153). The Didelphic ancestors of Man may have been
lly very different from all known Fossiled Antimalia (Mar-
), but possessed all the essential internal characters of
ialia.

(ii. 162). The phylogenetic of the Semi-opus, as the
al placental parent-group, is not influenced by our ignor-
any fossil Prosimiae, for it is never safe to [illegible]
ological facts as negative, but only as positive.

160 (ii. 168). On the structure of the Decidua very various theories have been given. Cf. Kölliker, "History of the Evolution of Man" ("Entwickelungsgeschichte des Menschen." 2nd edition, 1871, pp. 319–376). Ercolani (Giambattista), "Sul processo formativo della placenta." Bologna, 1870. "Le glandole otricolari del'utero." Bologna, 1868, 1873. Huxley, "Lectures on the Elements of Comparative Anatomy," 1864, pp. 101–112.

161 (ii. 172). Huxley, "Anatomy of Vertebrates," 1873, p. 382. Previously Huxley had separated the "Primates" into seven families of nearly equal systematic value. (See "Man's Place," etc., p. 119.)

162 (ii. 179). Darwin. Sexual selection in Apes and Man.—"Descent of Man," vol. ii. pp. 210–355.

163 (ii. 180). Man-like Holy Apes. Of all Apes, some Holy Apes (*Semnopithecus*) most resemble Man, in the form of their nose and the character of their hair (both that on the head and that on the beard).—Darwin, "Descent of Man," vol. i. p. 335; vol. ii. p. 172.

164 (ii. 182). Friedrich Müller ("Allgemeine Ethnographie." Vienna, 1873, p. 29), on the supposed age of man. Families of languages (pp. 5, 15, etc.).

165 (ii. 183). The plate (XV.) representing the migrations, given in the "History of Creation," merely claims the value of a first attempt, is an hypothetic sketch, as I there expressly said, and as, in consequence of repeated attacks, I must here insist.

166 (ii. 201). The Leather-plate. The phylogenetic distinction of a special leather-plate, the outermost lamella separating from the skin-fibrous layer, is justified by Comparative Anatomy.

167 (ii. 204). Milk-glands. Huss, "Contributions to the History of the Evolution of the Milk-glands" ("Beiträge zur Entwickelungsgeschichte der Milchdrüsen"); and Gegenbaur, "On the Milk-gland Papillæ" ("Jenaische Zeitschrift für Naturwissenschaft," 1873, vol. vii. pp. 176, 204).

168 (ii. 208). On the hairy covering of Man and Apes, see Darwin, "Descent of Man," vol. i. pp. 20, 167, 180; vol. ii. pp. 280, 298, 335, etc.

169 (ii. 217). Dorsal side and ventral sides are homologous in Vertebrates, Articulated Animals (*Arthropoda*), Soft-bodied Animals (*Mollusca*), and Worms, so that the dorsal marrow and the ventral marrow are not comparable. Cf. Gegenbaur, "Morph. Jahrbuch," vol. i. pp. 5, 6.

170 (ii. 228). The unknown ontogenetic origin of the sympathetic nerve-system must probably, for phylogenetic reasons, be sought chiefly in the intestinal layer, *not* in the skin-layer.

171 (ii. 248). On the cavities connected with the nose, see Gegenbaur, "Elements of Comparative Anatomy," p. 580.

172 (ii. 260). The analogies in the germination of the higher sense organs were rightly grasped even by the earlier natural philosophers. The first more accurate sketches of the very obscure germ-history of the sense-organs, especially of the eye and ear, were given (1830) by Emil Huschke, of Jena (Isis, Meckel's Archiv, etc.).

173 (ii. 265). Hasse, "Anatomical Studies" ("Anatomische Studien"), chiefly of the organ of hearing. Leipzig, 1873.

174 (ii. 269). Johannes Rathke, "On the Gill-apparatus and the Tongue-bone" ("Ueber den Kiemen-apparat und des Zungenbein," 1832). Gegenbaur, "On the Head-skeleton of Selachii," 1872. (See note 124.)

175 (ii. 272). On the Rudimentary Ear-shell of Man, cf. Darwin, "Descent of Man," vol. i. pp. 17–19.

176 (ii. 276). Scarcely anywhere does Comparative Anatomy prove its high morphological value as with reference to the skeleton of Vertebrates: in this matter it accomplishes much more than Ontogeny. There is all the more reason to insist on this here, as Goette, in his gigantic history of the evolution of Bombinator, has recently denied all scientific value to Comparative Anatomy, and asserted that Morphology is explained solely by Ontogeny. Cf. my "Aims and Methods of the Recent History of Evolution" ("Ziele und Wege der heutigen Entwickelungsgeschichte," 1875, p. 52, etc.).

177 (ii. 283). The Human Tail, like all other rudimentary organs, is very variable in point of size and development. In

rare cases it remains permanently, projecting freely: usual disappears at an early period, as in Anthropoid Apes.

178 (ii. 284). On the Number of Vertebræ in different M mals, cf. Cuvier, "Leçons d'Anatomie Comparée." 2nd edi tome i., 1835, p. 177.

179 (ii. 293). On the earlier Skull-theory of Goethe and O cf. Virchow, "Goethe as a Naturalist" ("Goethe als N forscher," 1861, p. 103).

180 (ii 295.). Karl Gegenbaur, "The Head-skeleto Selachii" ("Das Kopfskelet der Selachier"). As the found of a study of the head-skeleton of Vertebrates (1872).

181 (ii. 301). Karl Gegenbaur, "On the Archipterygi —"Jenaische Zeitschrift für Naturwissenschaft," vol. vii. p. 131.

182 (ii. 304). Gegenbaur, "Researches into the Compa Anatomy of Vertebrates" ("Untersuchungen zur Verglei den Anatomie der Wirbelthiere"). Part I. Carpus and T (1864). Part II. The shoulder girdle of Vertebrates. Pe fins of Fishes (1866).

183 (ii. 305). Charles Martins, "Nouvelle comparaiso membres pelviens et thoraciques chez l'homme et ch mammifères."—"Memoires de l'Acad. de Montpellier," v 1857.

184 (ii. 308). Ossification. Not all bones of the huma are first formed of cartilage. Cf. Gegenbaur, "On Prima Secondary Bone-formation, with special reference to th mordial Skull Theory."—"Jenaisch. Zeitschrift für wissenschaft," 1867, vol. iii. p. 54.

185 (ii. 308). Johannes Müller, "Comparative Anato Myxinoides."—"Transactions of the Berlin Academy," 1834

186 (ii. 314) The Homology of the Primitive Intesti the two primary germ-layers is the postulate for morpho comparison of the various Metazoa-tribes.

187 (ii. 322). In the Evolution of the Intestine, Amphi Ganoids have, by heredity, retained the original Craniot more accurately than have Selachii and Osseous Fishes (*Te*

palingenetic germination of Selachii has been much altered
nogenetic adaptations.

38 (ii. 323). On the Homology of Scales and Teeth, cf.
nbaur, "Comparative Anatomy" ("Grundriss der vergl.
omie," 1874, pp. 426, 582); also Oscar Hertwig, "Jenaische
chrift für Naturwissenschaft," 1874, vol. viii. On the
rtant distinction of homology (morphological resemblance)
Analogy (physiological resemblance), see Gegenbaur, as
, p. 63; also my "Generelle Morphologie," vol. i. p. 313.

39 (ii. 337). Wilhelm Müller, "On the Hypobranchial
ve in Tunicates, and its Presence in the Amphioxus and
stomi."—"Jenaische Zeitschrift für Naturwissenschaft,"
, vol. viii. p. 327.

90 (ii. 358). The Nerve-muscular Cells of the Hydra throw
arliest light on the simultaneous, phylogenetic differentiation
rve and muscle tissue. Cf. "Klemenberg, Hydra." Leipzig,

91 (ii. 383). The germ-history of the human heart accurately
oduces in all essential points its tribal history. This palin-
tic reproduction is, however, much contracted in particular
ts and vitiated by kenogenetic modifications of the original
se of evolution, displacements partly in time, partly in place,
h are the result of embryonic adaptations.

92 (ii. 383). On the Special Germ-history of the Human
ular system, cf. Kölliker, "History of the Evolution of Man"
twickelungsgeschichte des Menschen." 2nd edition, 1876);
Rathke's excellent work on Ontogeny.

93 (ii. 387). The Homologies of the Primitive Organs, as
are here provisionally described in accordance with the
ræa-theory (note 24), can only be established by further co-
ation between Comparative Anatomy and Ontogeny. Cf.
nbaur on Comparative Anatomy ("Grundriss der verglei-
den Anatomie").

94 (ii. 390). The Mechanism of Reproduction. As the
tions of reproduction and of heredity, connected with re-
uction, are referable to growth, so the former as well as the

latter are finally explicable as the results of the attraction and rejection of homogeneous and heterogeneous particles.

195 (ii. 397). Eduard van Beneden, "De la Distinction originelle du Testicule et de l'Ovaire." Brussels, 1874.

196 (ii. 399). On the Original Hermaphrodite Structure of Vertebrates, cf. Waldeyer, "Ovary and Egg" ("Eierstock und Ei," 1872, p. 152); also Gegenbaur ("Grundriss der vergleichenden Anatomie," 1874, p. 615). On the origin of the eggs from the ovary-epithelium, cf. Pflüger, "On the Ovaries of Mammals and Man" ("Die Eierstöcke der Säugethiere und des Menschen," 1863).

197 (ii. 423). On the special germ-history of the urinary and sexual organs, cf. Kölliker, "History of the Evolution of Man." On the homologies of these organs, see Gegenbaur ("Grundriss der vergleichenden Anatomie," 1874, pp. 610–628).

198 (ii. 448). Wilhelm Wundt, "Lectures on the Human and Animal Mind" ("Vorlesungen über die Menschen- und Thierseele." 1863). W. Wundt, "Outlines of Physiological Psychology" ("Grundzüge der Physiologishen Psychologie," 1874).

199 (ii. 457). On Active (actual) and Latent (preteritial) forces, cf. Hermann Helmholtz, "Interoperation of Natural Forces" ("Wechselwirkung der Naturkräfte," Part II., 1871).

200 (ii. 457). "Anthropology as Part of Zoology."—"Generelle Morphologie," vol. ii. p. 432. "History of Creation," vol. i. 7; vol. ii. 347.

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